

## **Chapter 11**

### **Vapor – Liquid Separation Processes**

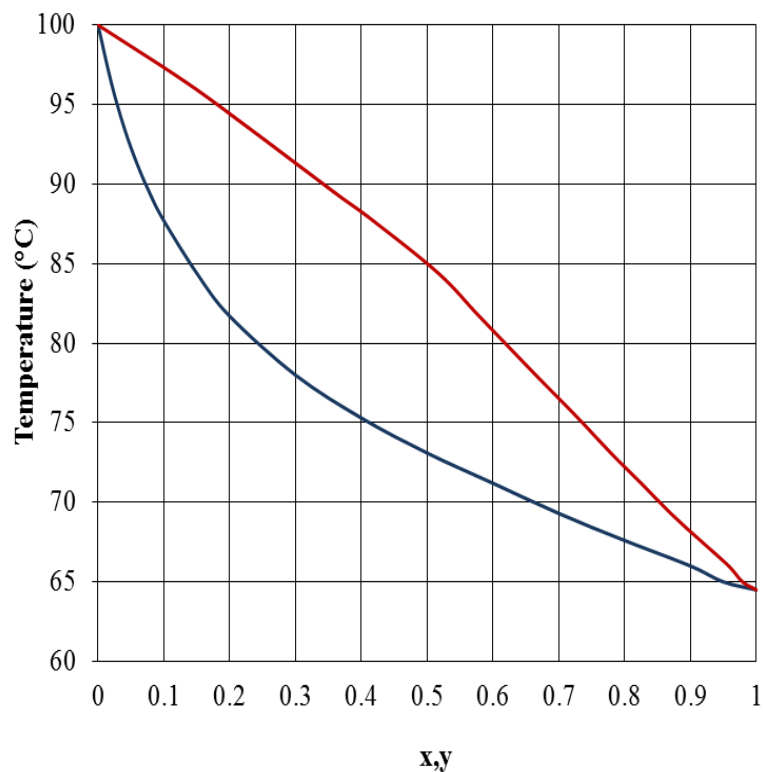
Separation processes in Chemical Engineering are used to transform a mixture of substances into two or more different products. In this chapter, the following problem modules illustrate the principles of chemical processes in which the separation involves the vapor and liquid phases.

11.1-1 Use of Raoult's Law for Methanol – Water Equilibrium Data

11.3-1 Relative Volatility of Methanol – Water Mixture

**Example 11.1-1: Use of Raoult's Law for Methanol – Water Equilibrium Data**

A methanol – water mixture is assumed to be in equilibrium with the vapor phase in the reservoir for a Direct – Methanol Fuel Cell. Using the following equilibrium data [1,2] and Raoult's Law determine the composition of the vapor and liquid phases at 72°C and 101.325 kPa. The vapor pressure data for water was obtained from Appendix A.2 of Geankoplis.



| T (°C) | P <sup>sat</sup> <sub>H<sub>2</sub>O</sub> (kPa) | P <sup>sat</sup> <sub>CH<sub>3</sub>OH</sub> (kPa) |
|--------|--------------------------------------------------|----------------------------------------------------|
| 64.5   | 24.521                                           | 100.74                                             |
| 65     | 25.03                                            | 102.66                                             |
| 66     | 26.57                                            | 106.73                                             |
| 67.6   | 28.233                                           | 113.68                                             |
| 69.3   | 30.328                                           | 121.06                                             |
| 71.2   | 32.964                                           | 129.41                                             |
| 73.1   | 35.772                                           | 139.55                                             |
| 75.3   | 39.109                                           | 151.28                                             |
| 78     | 43.866                                           | 167.02                                             |
| 81.7   | 50.94                                            | 190.44                                             |
| 84.4   | 56.577                                           | 209.96                                             |
| 87.7   | 64.477                                           | 234.53                                             |
| 89.3   | 68.417                                           | 248.34                                             |
| 91.2   | 73.598                                           | 264.85                                             |
| 93.5   | 80.227                                           | 285.04                                             |
| 96.4   | 89.254                                           | 313.83                                             |
| 100    | 101.325                                          | 351.38                                             |

**Strategy**

We need to use Raoult's Law to obtain the composition of both phases at the given temperature and pressure.

**Solution**

The following equation describes Raoult's Law:

$$y_A = \frac{P_A}{P}$$

1. Wankat, P.C., Separation Process Engineering, Second Edition, Prentice Hall, 2007.
2. Methanex Corporation. "Technical Information & Safe Handling Guide for Methanol" September 2006. Accessed: February 2011. [http://www.methanex.com/products/documents/TISH\\_english.pdf](http://www.methanex.com/products/documents/TISH_english.pdf)

In this problem, A = Methanol and B = Water. As we can see, we cannot yet determine the composition of the vapor phase because we need to calculate the composition of the liquid phase first. This can be done using Equation 11.1-3 of Geankoplis, given by:

$$P_A x_A + P_B (1 - x_A) = \text{_____}$$

We can use the pressures  $P_A$  and  $P_B$ , using linear interpolation of the given data, at the temperature of  $72^\circ\text{C}$ . Thus,

$$\frac{P_{A@T=72^\circ\text{C}} - P_{A@T=71.2^\circ\text{C}}}{P_{A@T=73.1^\circ\text{C}} - P_{A@T=71.2^\circ\text{C}}} = \frac{\text{_____}^\circ\text{C} - \text{_____}^\circ\text{C}}{73.1^\circ\text{C} - \text{_____}^\circ\text{C}}$$

Solving for the pressure  $P_{A@T=72^\circ\text{C}}$  we determine the pressure to be:

$$P_{A@T=72^\circ\text{C}} = \text{_____ kPa}$$

Using the same procedure we can determine the pressure of water at  $72^\circ\text{C}$  to be:

$$P_{B@T=72^\circ\text{C}} = \text{_____ kPa}$$

Now we can substitute the pressure values into the equation for the total pressure, and solve for  $x_A$  to yield:

$$\text{_____} x_A + \text{_____} (1 - x_A) = 101.325$$

$$99.53x_A = \text{_____}$$

$$x_A = \text{_____}$$

Hence the molar fraction of water is given by:

$$x_B = 1 - x_A = 1 - \text{_____}$$

$$x_B = \text{_____}$$

Now we can enter the value of  $x_A$  into Raoult's Law to determine  $y_A$  and  $y_B$ . Thus,

$$y_A = \frac{\text{_____ kPa}(\text{_____})}{101.325 \text{ kPa}}$$

$$y_A = \text{_____}$$

$$y_B = 1 - y_A = 1 - \text{_____}$$

$$y_B = 0.109$$

### Example 11.3-1: Relative Volatility of Water – Methanol Mixture

Determine the relative volatility of the methanol – water mixture described in problem 11.1-1 at the temperature of 72°C.

#### Strategy

Section 11.3B of Geankoplis gives an Equation for determining the relative volatility

#### Solution

The relative volatility of a mixture is defined by equation 11.3-3 of Geankoplis, shown below:

$$\alpha_{AB} = \frac{P_A}{P_B}$$

We can substitute the saturation pressures at the temperature of 72°C, which are given in Example 11.1-1. Thus, the relative volatility is found to be:

$$\alpha_{AB} = \frac{\text{_____ kPa}}{\text{_____ kPa}}$$

|                              |
|------------------------------|
| $\alpha_{AB} = \text{_____}$ |
|------------------------------|