**CBE 333: Chemical and Biological Engineering Lab I**

**Distillation Pre-Lab Assignment**

**Fall 2016**

**Reading assignment:**

1. Laboratory Handout: Distillation

2. Unit Operations of Chemical Engineering

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pg 712-720

**Problems:**

1. For binary mixtures of isopropanol and water at a pressure of 0.9 atm:
   1. Graph T versus y and T versus x on the same plot.
   2. Construct a second graph showing y versus x.
   3. Obtain an equation describing y as a function of x at equilibrium for points at isopropanol concentrations below the azeotrope.

Use Antoine’s equation to get the saturation vapor pressures. The vapor phase may be assumed to be ideal, but activity coefficients should be used to compensate for liquid-phase nonidealities.

Margules parameters for isopropanol(1)/water(2) are A12 = 1.97, A21 = 1.09

Where 

**Make extra copies of the y versus x diagram and the T versus x,y diagram and bring them to the distillation lab sessions so that you can make on-the-spot calculations.**

2. Using the RI calibration data in Table 2, prepare a plot of **mole fraction** of isopropanol in the liquid sample versus the Refractive Index reading. Fit the resulting curve with an appropriate calibration equation.

**Table 3.2: RI Calibration Data for Isopropanol-Water Mixtures.**

TA Data – Fall 2016

|  |  |  |
| --- | --- | --- |
| Vol % Isopropanol | RI | |
| 0 | 1.332 | 1.3334 |
| 10 | 1.339 |  |
| 20 | 1.3463 |  |
| 30 | 1.3536 |  |
| 40 | 1.3596 |  |
| 50 | 1.3662 | 1.3659 |
| 60 | 1.3690 |  |
| 70 | 1.3718 |  |
| 80 | 1.3750 |  |
| 90 | 1.3765 |  |
| 100 | 1.376 | 1.3769 |

3. A plant must distill a mixture containing 20 mol % isopropanol and 80 mol % water. The distillate is to contain 60 mol % isopropanol, and the bottom product should have less than 5 mol % isopropanol. The feed is a saturated liquid.

a) Construct a McCabe-Thiele diagram using the VLE curve from Prob. 1, and use it to determine

i) the minimum number of theoretical plates required

ii) the minimum reflux ratio, R = L/D

iii) the number of plates required if the reflux ratio is 1.4 times Rmin

iv) the optimum feed plate location if the reflux ratio is 1.4 times Rmin

b) Use the Fenske equation to calculate the minimum number of theoretical plates (at total reflux) required if the column is equipped with a partial reboiler and a total condenser.

c) If the overall plate efficiency is 75%, how many plates would actually be required at the reflux ratio specified in part (a iii)?

Appendix 1:

1. Antoine constants for log P sat = A − B/(T + C) with P sat in torr and T in °C.

TABLE 13-4 Antoine Vapor-Pressure Constants and Liquid Molar Volume\*

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Species | A | B | C | T range, C | V [ml/mol] |
| 2-propanol | 8.87829 | 2010.320 | 252.636 | (−30)–170 | 76.92 |
| Water | 8.07131 | 1730.630 | 233.426 | 1– 100 | 18.07 |

\*Abstracted from Gmehling and Onken, Vapor-Liquid Equilibrium Data Collection, DECHEMA Chemistry Data ser., vol. 1 (parts 1– 10), Frankfurt, 1977.

\*Source: Green, Don W., and Perry, Robert H.. Perry's Chemical Engineers' Handbook (8th Edition). Blacklick, OH, USA: McGraw-Hill Professional Publishing, 2007. ProQuest ebrary. Web. 20 October 2016.

1. Antoine constants for ln(P°, kPa) = A ‐ B/(TCelsius+C):

|  |  |  |  |
| --- | --- | --- | --- |
|  | A | B | C |
| Isopropanol | 16.678 | 3640.2 | 219.62 |
| Water | 17.014 | 4234.469 | 241.263 |

1. Azeotrope data for isopropanol/water

|  |  |  |
| --- | --- | --- |
|  | Boiling Point [C] | Wt % Isopropanol |
| Isopropanol | 82.5 | 1 |
| Water | 100 | 0 |
| Azeotrope | 80.4 | 0.879 |

1. Physical Properties

**Table 3.1 Physical Properties of Isopropanol and Water**. Isopropanol data from Flick, E.W. (1998). Industrial Solvents Handbook (5th Edition). William Andrew Publishing/Noyes. Water data from Perry's Chemical Engineers' Handbook (8th Edition). Blacklick, OH, USA: McGraw-Hill Professional Publishing, 2007.

|  |  |  |
| --- | --- | --- |
|  | Isopropanol | Water |
| Molar Mass [g/mol] | 60.09 | 18.02 |
| Density at 20 C [g/ml] | 0.79 | 1.0 |
| Liquid Heat Capacity at 20 C [cal/(g C)] | 0.696 | 1 |
| Heat of Vaporization at 20 C [cal/g] | 160 | 542 |