Quiz 5.3 – Mixtures and Phases

Name: Key

Use the table below to estimate the vapor phase mole fraction (y) for each component when 0.25 moles of chloroform are mixed with 0.75 moles of acetone

$$y_A = \frac{x_A p_A^*}{p_B^* + (p_A^* - p_B^*)x_A} = 1 - y_B$$

	CH_2O	$CHCl_3$
$p^*\ (kPa)$	46	35

$$y_{CH_2O} = \frac{0.75 \cdot 46\ kPa}{35\,kPa + (46\,kPa - 35\,kPa)\cdot 0.75} = 0.80 \qquad y_{CHCl_3} = 0.20$$

Below are the bubble-point and dew-point curves (liquid/vapor composition curves) for a mixture of hexane in heptane. Consider a mixture of 10.0 g of hexane in 10.0 g of heptane at $T = 85°C$. Find the following for this mixture: ① The compositions of the liquid and vapor phases, and ② the fraction of molecules in the liquid phase. Note that the curves have been fit to cubic functions, which allows for precise answers.

→ 0.116 moles → 0.0998 moles

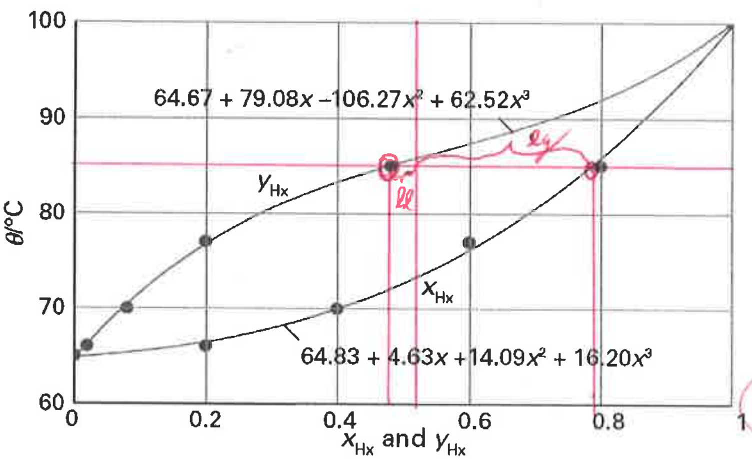


Figure 5C.8 The plot of data and the fitted curves for a mixture of hexane (Hx) and heptane in *Self-test* 5C.2.

$$Z_{Hx} = \frac{0.116\text{ moles}}{0.2158\text{ moles}} = 0.538$$

Y_{Hx} comes from solving:

$$85 = 64.67 + 79.08x - 106.27x^2 + 62.52x^3$$

$$Y_{Hx} = 0.477$$

X_{Hx} comes from solving:

$$85 = 64.83 + 4.63x + 14.09x^2 + 16.20x^3$$

$$X_{Hx} = 0.785$$

$$\ell_g = X_{Hx} - Z_{Hx} = 0.785 - 0.538 = 0.247$$

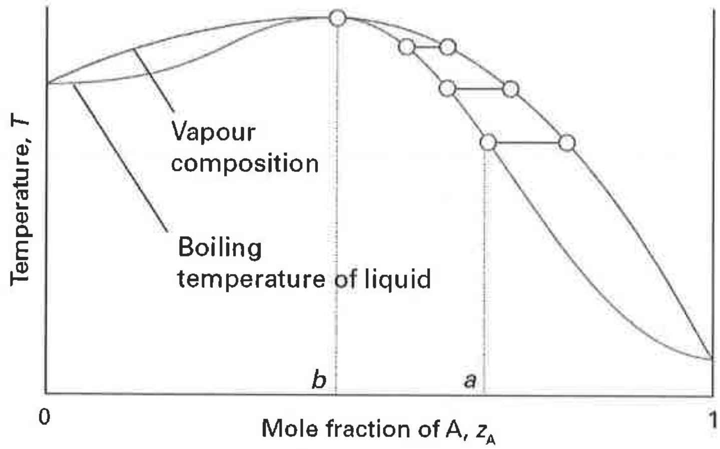
$$\ell_\ell = Z_{Hx} - Y_{Hx} = 0.538 - 0.477 = 0.061$$

$$\ell_{total} = X_{Hx} - Y_{Hx} = 0.785 - 0.477 = 0.308$$

$$\frac{n_\ell}{n_{total}} = \frac{\ell_\ell}{\ell_{total}} = \frac{0.061}{0.308} = 0.198$$

$$\frac{n_g}{n_{total}} = \frac{\ell_g}{\ell_{total}} = \frac{0.247}{0.308} = 0.802$$

Below are the composition curves for a certain azeotrope. Suppose you have a sample of this mixture with composition $Z_A = a$ (the dashed line marked a). In the limit of a many-stage distillation carried out until compositions are stable, what will be the compositions of the liquid and vapor phases?



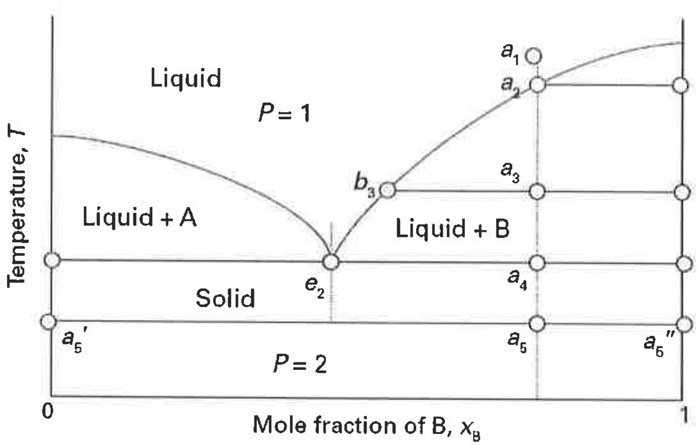
$X_A = b$

$Y_A = 1$

Figure 5C.12 A high-boiling azeotrope.

Below are the composition curves for a mixture near its freezing point. The eutectic composition (e_2 in the figure) is at $\chi_B = 0.42$. Suppose you have a liquid with 3.0 $moles$ of B and 1.0 $mole$ of A. This mixture has $\chi_B = 0.75$ (a in the figure), and is cooled slowly until it just reaches the eutectic freezing point. Find the following at this point: (1) The compositions of the solid and liquid phases, and (2) the number of moles in the solid phase.

B freezes out first until the eutectic point is reached



$X_B(s) = 1$

$X_B(l) = 0.42$

$$0.42 = \frac{\text{moles B in liquid}}{\text{total moles in liquid}}$$

$$0.42 = \frac{n_B(l)}{1 \text{ moles} + n_B(l)} \rightarrow n_B(l) = 0.72 \text{ moles}$$

Figure 5C.27 The temperature–composition phase diagram for two almost immiscible solids and their completely miscible liquids.

$n_B(s) = 3.0 \text{ moles} - n_B(l)$

$3.0 \text{ moles} - 0.72 \text{ moles} = 2.28 \text{ moles}$

At right is a diagram for two marginally miscible liquids. Consider a mixture with a temperature and composition indicated by point b_3.

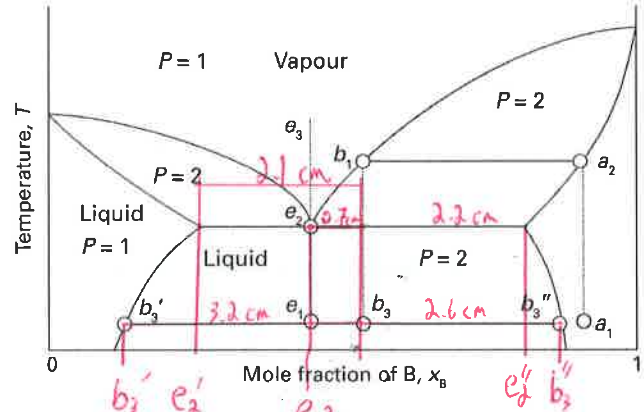


Figure 5C.21 The temperature–composition diagram for a binary system in which boiling occurs before the two liquids are fully miscible.

○ Give the number of phases, the composition of each phase, and the approximate ratio $\frac{n_i}{n_{total}}$ for each phase

2 phases

Phase	χ_B	$\frac{n}{n_T}$
1 (l)	b_3'	$\frac{2.6}{5.8} = 0.45$
2 (l)	b_3''	$\frac{3.2}{5.8} = 0.55$

This mixture is then heated until it reaches the minimum boiling point marked by the azeotrope point $e2$. Note that this temperature is marked by a black line on the diagram.

○ Give the number of phases, the composition of each phase, and the approximate ratio $\frac{n_i}{n_{total}}$ for each phase at this temperature

3 phases

Phase	χ_B	$\frac{n}{n_T}$
1 (l)	e_2'	~~$\frac{2.1}{4.3}$ 0.49~~ $\frac{2.2}{4.3} = 0.51$, toward Ø
2 (l)	e_2''	$\frac{2.1}{4.3} = 0.49$, move toward 0.24
3 (g)	e_2	Start @ Ø, move toward $\frac{2.2}{2.9} = 0.76$

This is an interesting point. It starts with the 2 liquid phases. As heat is added, vaporization occurs, increasing $n_{(g)}$ until phase 1 is gone. During this phase change, T, $\chi_B(1)$, $\chi_B(2)$, and $\chi_B(3)$ are all constant!

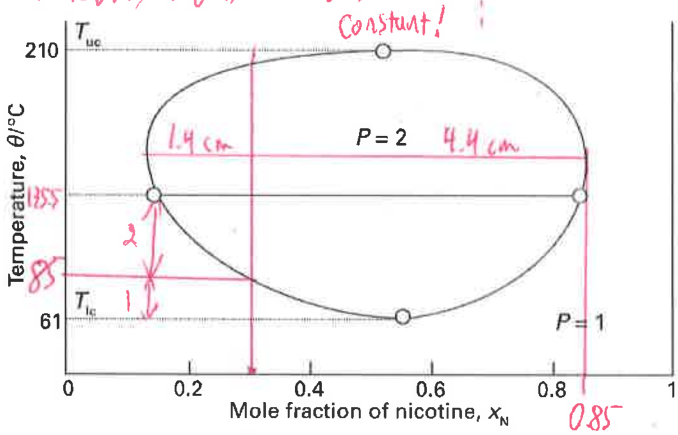


Figure 5C.19 The temperature–composition diagram for water and nicotine, which has both upper and lower critical temperatures. Note the high temperatures for the liquid (especially the water): the diagram corresponds to a sample under pressure.

At left is a phase diagram for a mixture of nicotine and water

○ You have a mixture with $\chi_N = 0.30$ at room temperature. As you heat the mixture, at some point it suddenly splits into two phases. At what temperature (approximately) does this split occur?

$\approx 85\,°C$

As you heat the mixture, you find that one phase is much more concentrated in nicotine and you decide to use this phenomenon to purify your nicotine mixture.

○ What is the highest concentration of nicotine that you can hope to achieve?

≈ 0.85

○ What fraction of the mixture will be in this concentrated phase?

$\frac{1.4}{5.8} = 0.24$