# Differential Distillation



**100 moles of Benzene (A) and Toluene mixture containing 50% (mole) of Benzene is subjected to a differential distillation at atmospheric pressure till the composition of benzene in the residue is 33%. Calculate the total moles of the mixture distilled. Average relative volatility may be assumed as 2.16**

**Calculations:**

For system of constant relative volatility, the following equation is obtained after the simplification of Rayleigh's equation for differential distillation:

$$\ln \frac{F}{W} = \frac{1}{\alpha - 1} \ln \frac{x_F(1 - x_W)}{x_W(1 - x_F)} + \ln \frac{1 - x_W}{1 - x_F}$$

In the above equation, F is feed; W is residue; $x_F$ is composition of feed; $x_W$ is composition of residue; and $\alpha$ is relative volatility.

Given: $x_F = 0.5$; $x_W = 0.33$; F = 100; $\alpha = 2.16$

Substituting these in the above equation,

ln (100/W) = (1/1.16) x ln {[(0.5(1 - 0.33)]/[(0.33(1 - 0.5)]} + ln [(1 - 0.33)/(1 - 0.5)]

ln (100/W) = 0.862 x ln (2.03) + ln (1.34)

ln (100/W) = 0.862 x 0.708 + 0.2927

ln (100/W) = 0.903

$100/W = e^{0.903}$

100/W = 2.467

W = 100/2.467 = 40.54 mole

Moles of mixture distilled = F - W = 100 - 40.54 = 59.46

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The above can also be obtained by using the general form of Rayleigh's equation and by graphical method. This is given below.

The equilibrium curve relationship is given by

$y^* = \alpha x/(1 + x(\alpha - 1)) = 2.16x/(1 + 1.16x) \rightarrow 1$

For differential distillation, the following Rayleigh's equation is applicable:

$$\ln \frac{F}{W} = \int_{x_W}^{x_F} \frac{dx}{y^* - x} \quad \rightarrow 2$$

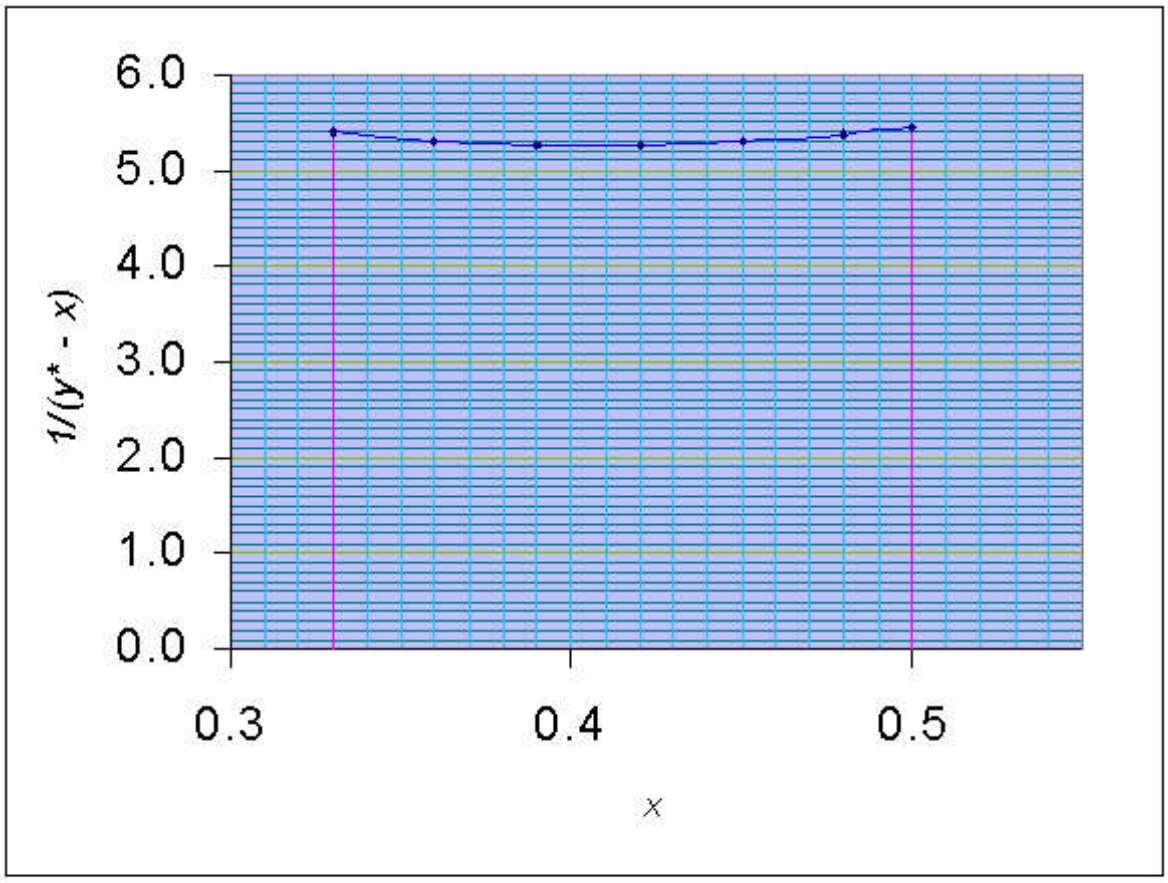
By using Equn.1 the following equilibrium data is obtained: (for the region of $x$ = 0.33 to 0.5)

| $x$ | $y^*$ |
|---|---|
| 0.33 | 0.515 |
| 0.36 | 0.549 |
| 0.39 | 0.580 |
| 0.42 | 0.610 |
| 0.45 | 0.639 |
| 0.48 | 0.666 |
| 0.5 | 0.684 |

For the above data the following table of $x$ Vs.$1/(y^* - x)$ is obtained:

| x | 1/(y* - x) |
|---|---|
| 0.33 | 5.392 |
| 0.36 | 5.304 |
| 0.39 | 5.263 |
| 0.42 | 5.263 |
| 0.45 | 5.301 |
| 0.48 | 5.377 |
| 0.5 | 5.448 |

Using the above data a graph of $x$ Vs.$1/(y^* - x)$ is drawn between the limits of $x$ = 0.33 to 0.5.




Number of small squares under the curve between $x = 0.33$ and $0.5 = 904$
Therefore, area under the curve $= 904 \times 0.01 \times 0.1 = 0.904$

Area under the curve between the limits of $x$ = 0.33 to 0.5, is = 0.904

i.e.,

ln (F/W) = 0.904

$e^{0.904}$ = F/W

2.4695 = F/W

Given F = 100 moles. Therefore,

W = 100 / 2.4695 = 40.5 mole.

Therefore, moles of mixture distilled = F - W = 100 - 40.5 = 59.5

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