WORKED EXAMPLES

1. Compute the equilibrium data from the following data at 760 mm Hg pressure and calculate the relative volatility.

VP of A, mm Hg	760	830	920	1060	1200	1360
VP of B, mm Hg	200	350	420	550	690	760

$P_T = 760$ mm Hg

Solution.

P_A, mm Hg	760	830	920	1060	1200	1360
P_B, mm Hg	200	350	420	550	690	760

We know that $x_A = \left[\frac{(P_T - P_B)}{(P_A - P_B)}\right]$ and $y_A = \left[\frac{(P_A x_A)}{P_T}\right]$

$x_A = \left[\frac{(P_T - P_B)}{(P_A - P_B)}\right]$	1.0	0.854	0.68	0.412	0.137	0
$y_A = \left[\frac{(P_A x_A)}{P_T}\right]$	1.0	0.933	0.823	0.575	0.216	0
α_{AB} = VP of A/VP of B	3.80	2.37	2.19	1.93	1.74	1.79

Average relative volatility: 2.303

2. The vapour pressure data for *n*–Hexane –*n*–Octane system is given below. Compute the equilibrium data and relative volatility for the system at a total pressure of 101.32 kPa.

T°C	*n*-Hexane P_A,kPa (*A*)	*n*-Octane P_B,kPa (B)
68.7	101.32	16.1
79.4	136.7	23.1
93.3	197.3	37.1
107.2	284.0	57.9
125.7	456.0	101.32

Solution.

T°C	n-Hexane P_A,kPa (A)	n – Octane P_B,kPa (B)	$\alpha_{cal} = P_A/P_B$	$x_A = \frac{P_t - P_B}{(P_A - P_B)}$	$y_A = \frac{P_A x_A}{P_t}$	$y = \frac{\alpha x}{[1 + (\alpha - 1)x]}$
68.7	101.32	16.1	6.29	1.000	1.00	1.000
79.4	136.7	23.1	5.92	0.689	0.930	0.923
93.3	197.3	37.1	5.32	0.401	0.781	0.783
107.2	284.0	57.9	4.91	0.192	0.538	0.562
125.7	456.0	101.32	4.50	0	0	0

3. Compute x–y data at 1 atm. Pressure from the following data:

T	80.1	85	90	95	100	105	110.6
VP_A	760	877	1016	1168	1344	1532	1800
VP_B	–	345	405	475	577	645	760

Solution.

T	80.1	85	90	95	100	105	110.6
VP_A	760	877	1016	1168	1344	1532	1800
VP_B	—	345	405	475	577	645	760
$\alpha = \frac{VP_A}{VP_B}$	—	2.54	2.51	2.46	2.33	2.38	2.37

(Ans: $\alpha_{\text{average}} = 2.43$**)**

$x_A = \left[\frac{(P_T - P_B)}{(P_A - P_B)}\right]$	1.0	0.78	0.58	0.411	0.239	0.13	0
$y_A = \left[\frac{(P_A x_A)}{P_T}\right]$	1.0	0.9	0.777	0.632	0.423	0.26	0

4. A solution of methanol and ethanol are substantially ideal. Compute the VLE for this system at 1 atm pressure and relative volatility.

$$\log\,[P,\ \text{mm}]_{\text{Methanol}} = 7.84863 - \frac{1473.11}{(230 + t°C)}$$

$$\log\,[P,\ \text{mm}]_{\text{Ethanol}} = 8.04494 - \frac{1554.3}{(222.65 + t°C)}$$

Solution.

In this problem one has to compute the vapour pressure values at different temperatures. The temperature range is fixed by keeping the pressure as

760 mm Hg for each component. Thus, in the following equation for Methanol,

$$\log\,[P,\ \text{mm}]_{\text{Methanol}} = 7.84863 - \frac{1473.11}{(230 + t^\circ\text{C})}$$

Setting the vapour pressure as 760 mm Hg (at BP, vapour pressure equals the prevailing pressure), we get the temperature as 66.53°C, which is the boiling point of Methanol. Similarly, by setting P as 760 mm Hg in the equation for ethanol,

$$\log\,[P,\ \text{mm}]_{\text{Ethanol}} = 8.04494 - \frac{1554.3}{(222.65 + t^\circ\text{C})}$$

we get the boiling point of Ethanol as 78.33°C. This fixes the range of temperature.

t°C	66.53	70	72	74	76	78	78.33
V.P. of Methanol, P_A, mm	760	867.5	934.94	1006.6	1082.79	1163.6	1177.4
V.P. of Ethanol, P_B, mm	467.8	541.77	588.66	638.9	692.66	750.14	760
Relative volatility, $\alpha = \frac{P_A}{P_B}$	1.625	1.601	1.588	1.576	1.563	1.551	1.549
$x_A = \frac{P_t - P_B}{(P_A - P_B)}$	1.0	0.67	0.495	0.329	0.173	0.024	0.0
$y_A = \frac{P_A x_A}{P_t}$	1.0	0.765	0.609	0.436	0.246	0.0365	0.0

Average relative volatility = 1.579

5. Methanol and Ethanol form an ideal solution. Compute the VLE data at 760 mm Hg pressure,
Vapour pressure Data:

Vapour pressure, mm Hg	200	400	760	1520
Temperature,°C, Ethanol	48.4	62.5	78.4	97.5
Temperature,°C, Methanol	34.8	49.9	64.7	84.0

Plot vapour pressure vs temperature for both the components and compute T vs. VP for Methanol and T vs. VP for Ethanol as shown in Fig. 9.34.

Solution.

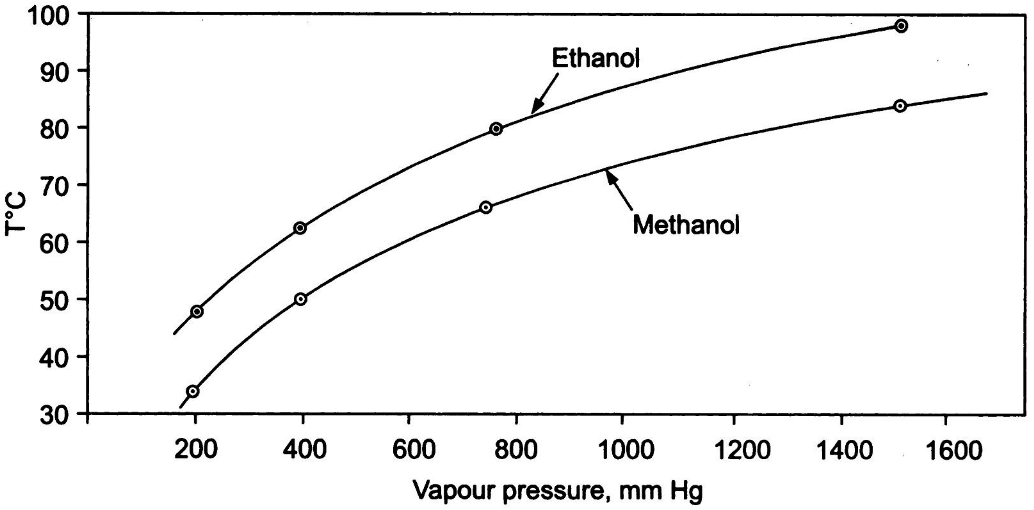

Fig. 9.34 Example 5 Vapour Pressure–temperature plot.

Temperature, °C	*V.P. of Ethanol,* mm Hg (*B*)	*V.P. of Methanol,* mm Hg (*A*)	$x_A = \frac{P_t - P_B}{(P_A - P_B)}$	$y_A = \frac{P_A x_A}{P_t}$
64.7	430	760	1.0	1.0
67.0	470	830	0.806	0.880
70.0	540	950	0.537	0.671
73.0	620	1080	0.304	0.432
76.0	700	1200	0.120	0.189
78.4	760	1300	0.0	0.0

6. It is desired to separate a feed mixture containing 40% heptane and 60% ethyl benzene, such that 60% of the feed is distilled out. Estimate the composition of the residue and distillate when the distillation process is (i) equilibrium distillation, and (ii) differential distillation.

Equilibrium Data:

x	0	0.08	0.185	0.251	0.335	0.489	0.651	0.79	0.914	1.0
y	0	0.233	0.428	0.514	0.608	0.729	0.814	0.910	0.963	1.0

x, *y*: Mole fraction of heptane in liquid and vapour phase respectively.

Solution.

(i) Plot the equilibrium data and draw the diagonal.

Draw a line with a slope of –W/D = – 0.4/0.6 = –0.667 from a point on the diagonal corresponding to x_F = 0.4 and its intersection on the equilibrium curve and read them as x_w and y_D as shown in Fig. 9.35.

$$x_w = 0.24 \text{ and } y_D = 0.5$$

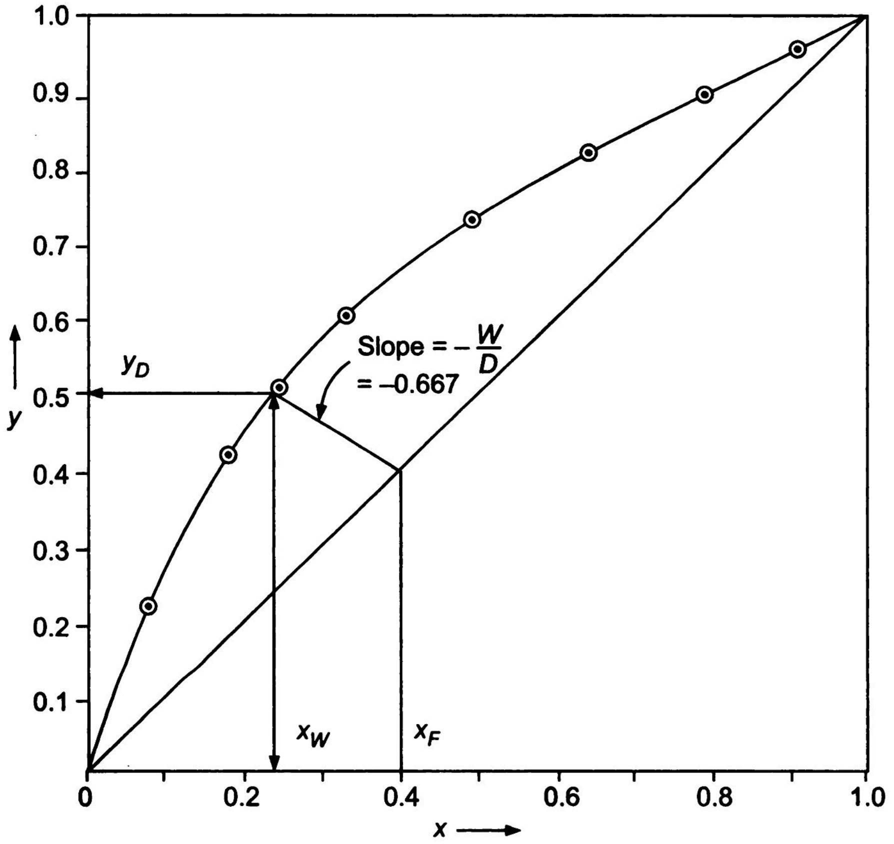

Fig. 9.35 Example 6 Solution for flash distillation.

(ii) Compute $\frac{1}{y-x}$ and plot it against x as shown in Fig. 9.36

x	0	0.08	0.185	0.251	0.335	0.489	0.651	0.79	0.914	1.0
y	0	0.233	0.428	0.514	0.608	0.729	0.814	0.91	0.963	1.0
$y-x$	0	0.153	0.243	0.263	0.273	0.240	0.163	0.12	0.049	0
$\frac{1}{y-x}$	α	6.54	4.12	3.80	3.66	4.17	6.13	8.33	20.41	α

We know that

$$\int_{x_w}^{x_F} \frac{dx}{(y-x)} = \ln\left[\frac{F}{W}\right] = \ln\left[\frac{1}{0.4}\right] = 0.916$$

By trial and error, find the x-co-ordinate which will give the area under the curve as 0.916 from x_F = 0.4. x_w = 0.2. By making component balance, y_D = 0.533.

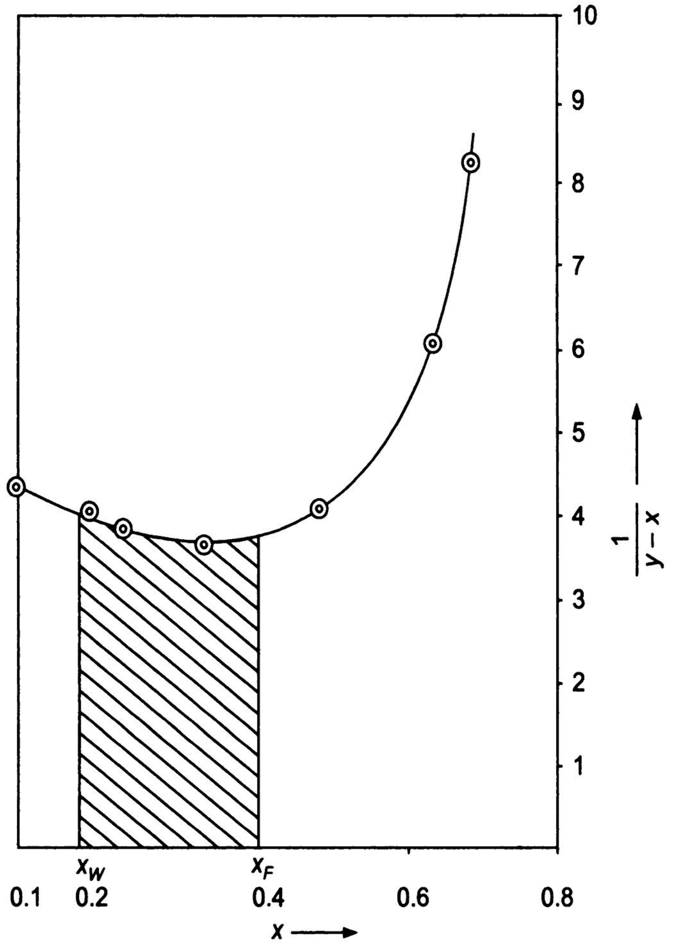

Fig. 9.36 Example 6 Solution for differential distillation.

7. A feed mixture containing 50 mole % Hexane and 50 mole % Octane is fed into a pipe still through a pressure reducing valve and flashed into a chamber. The fraction of feed converted to vapour is 0.6. Find the composition of the distillate and residue

x	0	4.5	19.2	40	69	100
y	0	17.8	53.8	78	93.2	100

x, y mole percent of Hexane in liquid and vapour phase respectively

Solution.

Draw the equilibrium curve and diagonal. From the feed point draw a line with a slope of

$$\left[-\frac{W}{D}\right] = -\frac{0.4}{0.6} = -0.667$$

From graph shown in Fig. 9.37, we get

$$x_W = 0.275, \quad y_D = 0.65$$

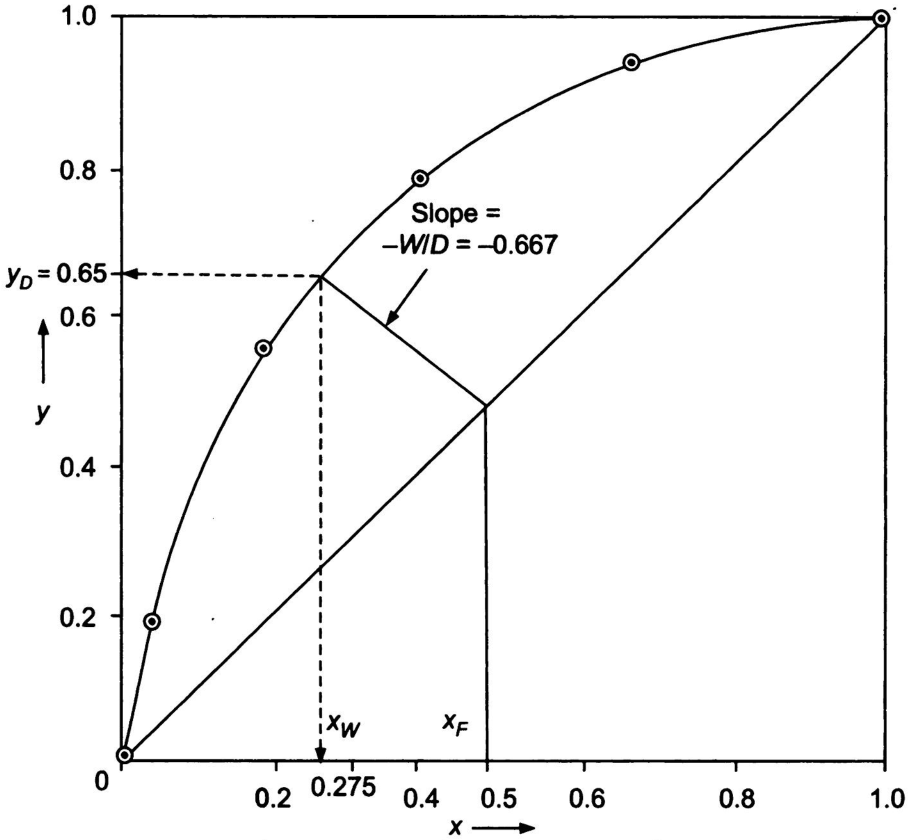

Fig. 9.37 Example 7 Flash distillation.

8. A equimolar feed mixture containing A and B is differentially distilled such that 70% of the feed is distilled out. Estimate the composition of the distillate and residue.

Equilibrium data

x	0	1	8	14	21	29	37	46	56	66	97	100
y	0	3	16	28	39	50	59	65	76	83	99	100

x, y: mole fraction of benzene in liquid and vapour phase respectively.

Solution.

x	0	0.01	0.08	0.14	0.21	0.29	0.37	0.46	0.56	0.66	0.97	1.0
y	0	0.03	0.16	0.28	0.39	0.50	0.59	0.65	0.76	0.83	0.99	1.0
$y–x$	0	0.02	0.08	0.14	0.18	0.21	0.22	0.19	0.20	0.17	0.02	0
$\frac{1}{y-x}$	α	50	12.5	7.14	5.56	4.76	4.55	5.26	5.0	5.88	50	α

Plot $\frac{1}{y-x}$ against x as shown in Fig. 9.38

We know that,

$$\int_{x_w}^{x_F} \frac{dx}{(y-x)} = \ln\left[\frac{F}{W}\right]$$

Let the feed be 100 moles
Therefore, D = 70 moles and W = 30 moles

$$\therefore \qquad \ln\left[\frac{F}{W}\right] = \ln\left[\frac{100}{30}\right] = 1.204$$

By trial and error, locate x_w such that $\int_{x_w}^{x_F} \frac{dx}{(y-x)} = 1.204$

We get, $x_w = 0.23$

Making material balance, we get

$$F = W + D$$

$$Fx_F = W\,x_W + Dy_D$$

Substituting for various quantities, we get

$$100 \times 0.5 = 30 \times 0.23 + 70 \times y_D$$

Solving, we get,

$$y_D = 0.616$$

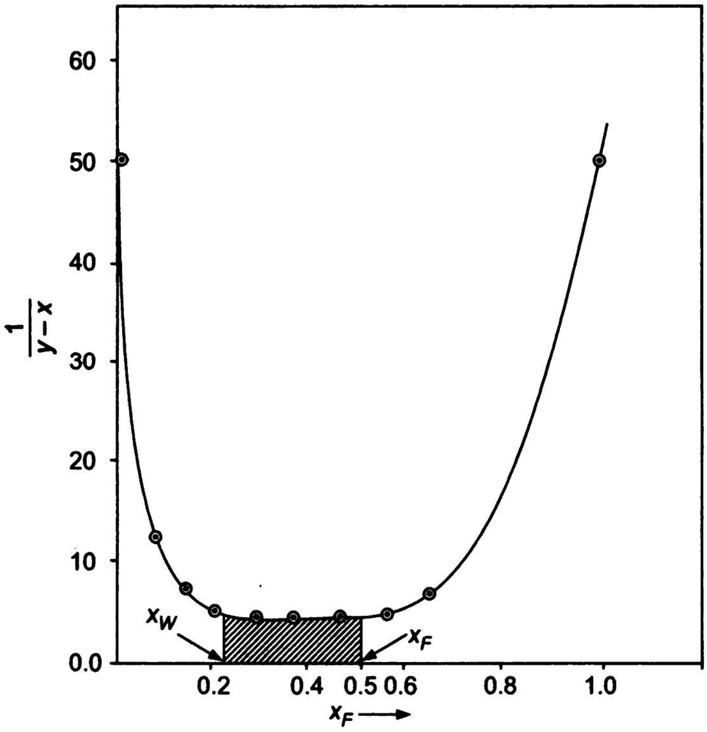

Fig. 9.38 Example 8 Solution for differential distillation.

9. A liquid mixture of components A and B containing 30 mole percent A is subjected to differential distillation. What percentage of the original mixture must be distilled off in order to increase the concentration of A in the residue to 65 mole percent?

The relative volatility of B in respect of A is 2.15.

Solution.

$$\ln\left[\frac{Fx_{F,B}}{WX_{W,B}}\right] = \alpha_{BA}\ln\left[\frac{Fx_{F,A}}{WX_{W,A}}\right]$$

$$\ln\left[\frac{F\times 0.7}{W\times 0.35}\right] = 2.15\ln\left[\frac{F\times 0.3}{W\times 0.65}\right]$$

$$2\left[\frac{F}{W}\right] = \left[\frac{F\times 0.4615}{W}\right]^{2.15}$$

Solving, we get $\left[\frac{F}{W}\right] = 7.75$

Therefore, if F = 100 kmol, W = 12.91 kmol.
Hence, 87.09% of feed has to be distilled.

10. Nitrobenzene (NB) has to be steam distilled. If the vaporization efficiency is 85%, estimate the amount of nitrobenzene in the distillate if 100 kg of steam is present in distillate. The distillation takes place at a total pressure of 760 mm Hg.

Vapour pressure data for nitrobenzene:

T°, C	44.4	71.6	84.9	99.3	115.4	125.8	139.9	185.8	210.6
VP of NB mm Hg	1	5	10	20	40	60	100	400	760

Vapour pressure of water:

T°C	20	40	60	80	100
VP of water, mm Hg	17.5	55.3	149.4	355.1	760

T (°C)	71	78	80	82	90	96	100
p_B	5	7.5	9	10	14	17.5	21
p_A	242.5	340	355	412.5	515	605	760

Solution.

From total vapour pressure curve: Boiling point of mixture = 99.0°C

At 99°C, vapour pressure of nitrobenzene = 20 mm Hg
vapour pressure of water = 740 mm Hg

Vaporization η = [(Actual NB/Actual water)]

$$0.85 = \left[\frac{\left[\dfrac{\text{Actual NB}}{\text{Actual water}}\right]}{\left[\dfrac{\text{Theoretical NB}}{\text{Theoretical water}}\right]}\right] \quad \text{(all in moles)}$$

$$\frac{\text{Actual NB}}{\text{Actual water}} = 0.85 \times \left[\frac{\text{Theoretical NB}}{\text{Theoretical water}}\right]$$

$$= \frac{0.85 \times 20 \times 123}{740 \times 18} \text{ kg of NB/kg of steam}$$

$$= 0.85 \times 0.1847 = 0.157 \text{ kg of NB/kg of steam}$$

Mass of NB per 100 kg of steam = 15.7 kg

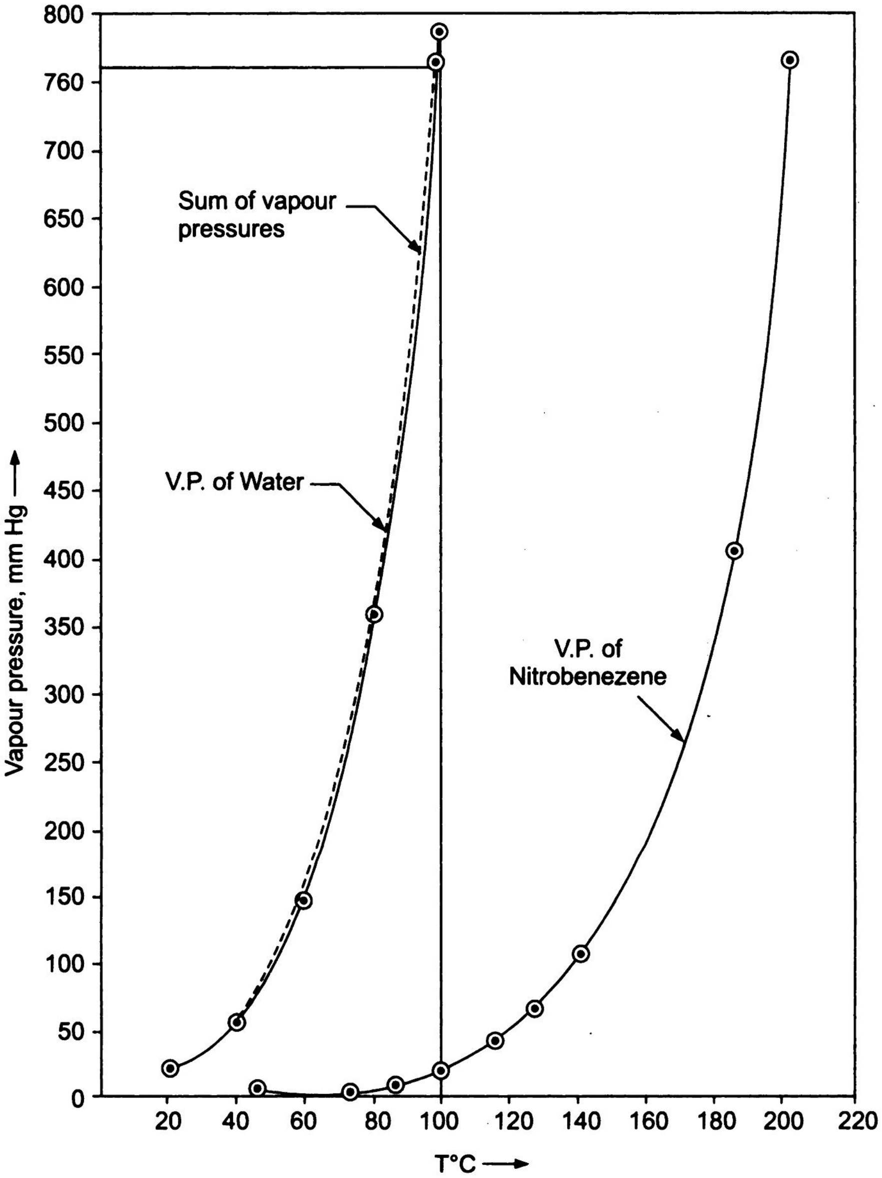

Fig. 9.39 Example 10 Determination of boiling point for steam distillation.

11. A methanol–water solution containing 36 mole % methanol at 26.7°C is continuously distilled to yield a distillate containing 91.5 mole % methanol and a residue containing 99 mole % water. The feed enters at its bubble point. Distillate is totally condensed and refluxed at its bubble point. (i) Find the minimum reflux ratio. (ii) For a reflux ratio of 3, estimate the number of plates by Ponchon–Savarit method.
Enthalpy data:

x or y mole fraction of methanol	*Enthalpies of saturated liquid* kJ/kmol	*Enthalpies of saturated vapour* kJ/kmol
0	8000	48000
1	7500	39000

Equilibrium data:

x, %	4	10	20	30	50	70	90	95
y, %	23	42	58	66	78	87	96	98.15

x, y are mole fractions of methanol in liquid and vapour phase respectively.

Solution.

(i) $x_F = 0.36$, $x_w = (1 - 0.99) = 0.01$, $x_D = 0.915$

Both feed and Reflux are at bubble point.

Plot H-x-y diagram and xy diagram as shown in Fig. 9.40.

By intrapolation, $H_{G1} = 39765$ kJ/kmol

Locate F corresponding to $x_F = 0.36$ on the bubble point curve.

Through F draw a tie line and extend it to intersect the vertical line drawn at $x_D = 0.915$

$$Q'_{\text{min}} \text{ (from graph)} = 62500 \text{ kJ/kmol}$$

$$R_{\text{min}} = \frac{(Q'_{\text{min}} - H_{G_1})}{(H_{G_1} - H_{L_0})} = \frac{(62500 - 39765)}{(39765 - 7542.5)} = 0.7056$$

Minimum reflux ratio = 0.7056

(ii) For $R = 3$

$$R = \frac{(Q' - H_{G_1})}{(H_{G_1} - H_{L_0})} = \frac{(Q' - 39765)}{(39765 - 7542.5)} = 3$$

$$Q' = 136432.5 \text{ kJ/kmol}$$

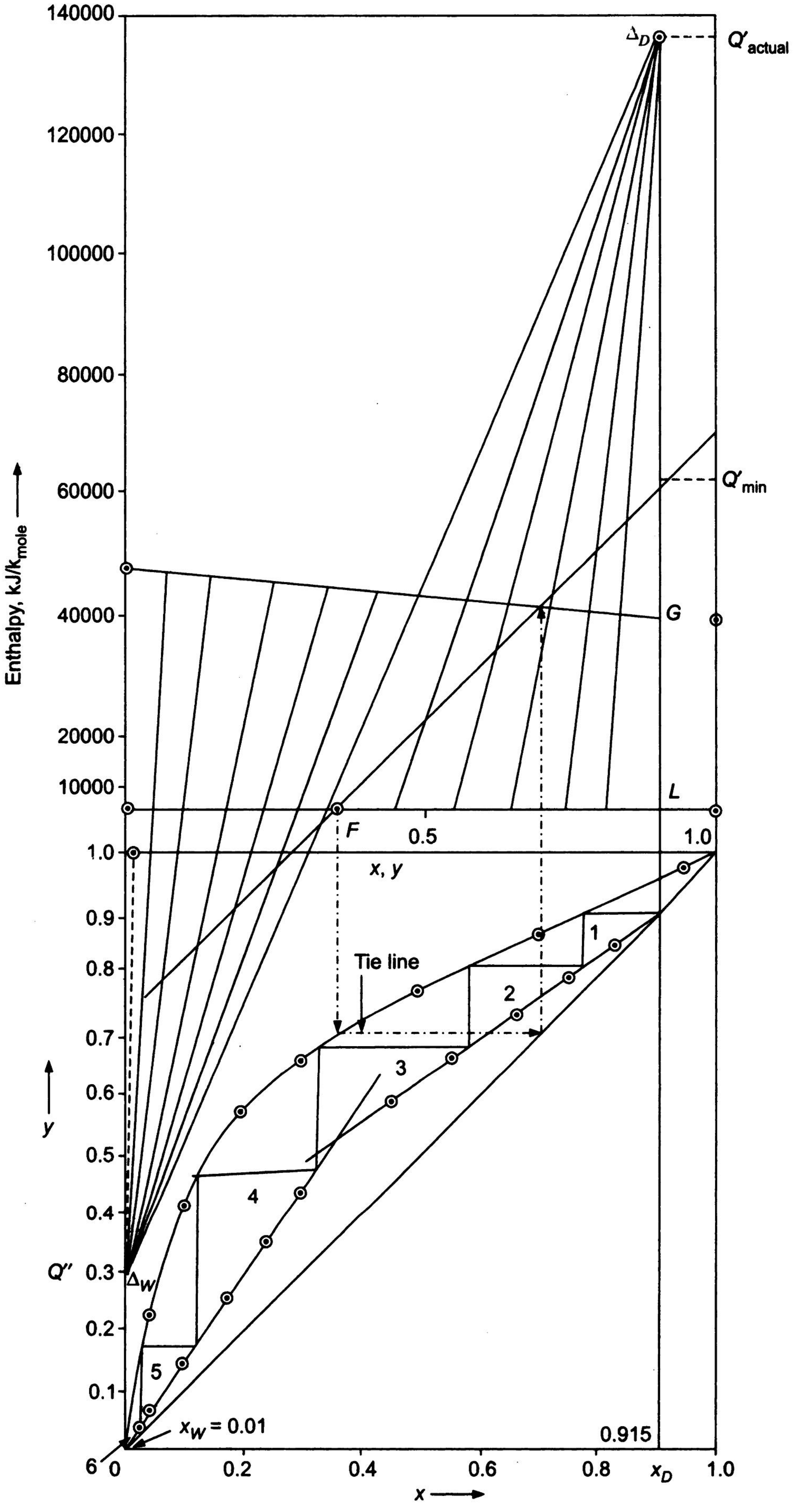

Fig. 9.40 Example 11 Ponchon–Savarit method.

We know that Δ_D, Δ_W and $F(Z_F, H_F)$ lie on a straight line

$$\frac{(Z_F - Z_w)}{(x_D - x_F)} = \frac{(H_F - Q'')}{(Q' - H_F)}$$

$$Q'' = -73004.5 \text{ kJ/kmol}$$

Locate $\Delta_D(Q', x_D)$ and $\Delta_w(Q'', x_w)$ on H_{xy} diagram. Randomly draw construction lines starting from Δ_D and Δ_w and obtain the operating curves for both sections on *xy*-diagram. Stepwise construction between equilibrium curve and operating curve will give the number of stages.

Number of stages (including reboiler) = 6

Number of plates in tower = 6 − 1 = 5

12. A continuous distillation column is used to separate a feed mixture at its boiling point, containing 24 mole % acetone and 76 mole % methanol into a distillate product containing 77 mole % acetone and a residue product containing 5 mole % acetone. A reflux ratio of twice the minimum is to be used. The overall plate efficiency is 60%. Determine the number of plates required for the separation.

Equilibrium data:

x	0.0	0.05	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
y	0.0	0.102	0.186	0.322	0.428	0.513	0.586	0.656	0.725	0.82	0.9	1.0

Solution.

x, y Mole fraction of acetone in liquid and vapour phase respectively.

$$x_F = 0.24, \qquad x_D = 0.77, \qquad x_w = 0.05$$

$R_{\text{actual}} = 2R_{\text{min}}$

$\eta_{\text{overall}} = 60\%$

Plot *xy* diagram and draw the feed line with its corresponding slope of infinity to equilibrium curve and let it be *F*. Let the point *D* on the diagonal corresponds to x_D. Join *DF* and extend it to *y*-axis. The point of intersection is

$$\frac{x_D}{R_{\text{min}} + 1} = 0.19 \text{ (from Fig. 9.41)}$$

$$\therefore \qquad R_{\text{min}} = 3.053$$

$$\therefore \qquad R_{\text{actual}} = 6.106$$

$$\frac{x_D}{R_{\text{actual}} + 1} = \frac{0.77}{7.106} = 0.108$$

Locate 0.108 on *y*-axis and let it be *A*. Join *AD*. The point of intersection of *AD* with feed line is *Q*. *DQ* is the operating line for enriching section. Locate *W* on diagonal corresponding to $x_W = 0.05$. Join *W* and *Q*. *WQ* is the operating line for stripping section. By stepwise construction the number of stages = 14 (including reboiler)

$\therefore$ Number of plates is 13 (Theoretical)

$$\text{Actual number of plates} = \frac{13}{0.6} = 21.7, \text{ i.e. 22 plates}$$

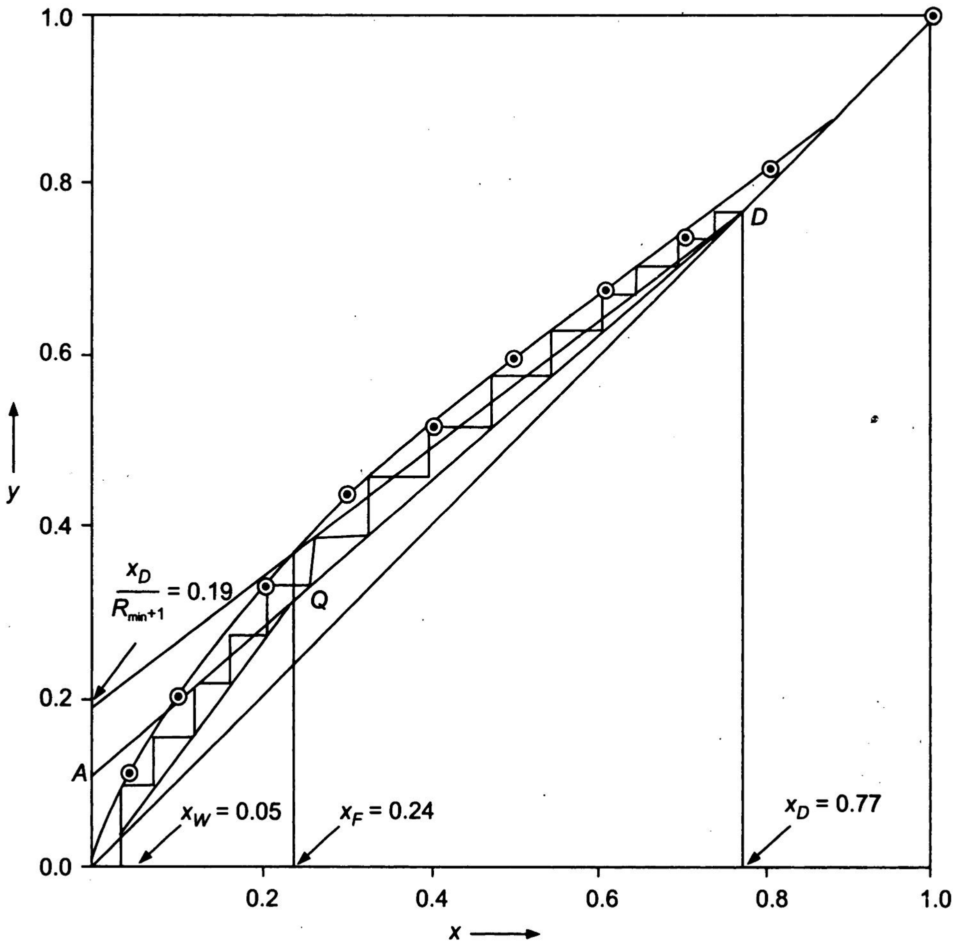

Fig. 9.41 Example 12 McCabe–Thiele method.

13. A fractionating column separates a liquid mixture entering at 5000 kmol/h containing 50 mole % A and 50 mole % B into an overhead product of 95 mole % A and a bottom product of 96 mole % B. A reflux ratio of twice the minimum will be used and the feed enters at its boiling point. Determine the number of theoretical stages required and the location of feed point.

Equilibrium data:

x	0.03	0.06	0.11	0.14	0.26	0.39	0.53	0.66	0.76	0.86	1.0
y	0.08	0.16	0.27	0.33	0.50	0.63	0.71	0.83	0.88	0.93	1.0

x, y mole fraction of A in liquid and vapour phase respectively.

Solution.

$$x_F = 0.5, \qquad x_D = 0.95, \qquad x_w = 0.04$$

Feed-saturated liquid

$$F = 5000 \text{ kmol/h}$$

Total condenser

(i) Total material balance

$$F = D + W$$

Component balance

$$Fx_F = Dx_D + Wx_W$$

$$5000 = \text{D} + W \qquad (1)$$

$$(5000 \times 0.5) = (D \times 0.95) + (W \times 0.04) \qquad (2)$$

$$5000 = D + W$$

$$\text{Distillate } D = 2527.5 \text{ kmol/h}$$

$$\text{Residue } W = 2472.5 \text{ kmol/h}$$

(ii) $R_{\min} = [(x_D - y')/(y' - x')]$

$$R_{\min} = \left[\frac{(0.95 - 0.720)}{(0.720 - 0.5)}\right] = 1.045$$

Also, by graphical $x_D/(R_{\min} + 1) = 0.46$ and $R_{\min} = 1.065$

(iii) $R_{\text{actual}} = 2 \times R_{\min}$

$R_{\text{actual}} = 2 \times R_{\min} = 2 \times 1.045 = 2.09$ (Taking $R_{\min}$ value as 1.045)

$$\frac{x_D}{(R+1)} = \frac{0.95}{(2.09+1)} = 0.307$$

With the above intercept, draw both enriching and stripping operating curves.
By McCabe–Thiele method,
Number of plates (including reboiler) = 11
Number of plates in tower = 11 − 1 = 10
The location of feed tray is 6th tray.

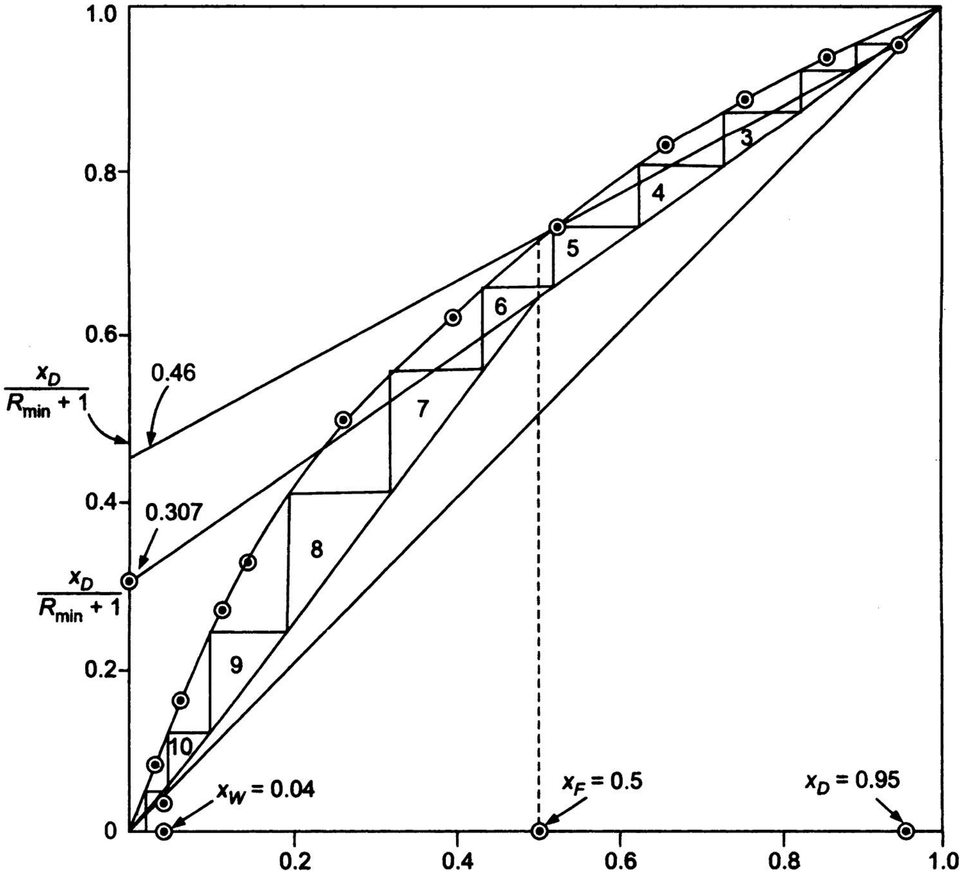

Fig. 9.42 Example 13 McCabe–Thiele method.

14. A mixture of benzene and toluene containing 38 mole % of benzene is to be separated to give a product of 90 mole % benzene at the top, and the bottom product with 4 mole % benzene. The feed enters the column at its

boiling point and vapour leaving the column is simply condensed and provide product and reflux. It is proposed to operate the unit with a reflux ratio of 3.0. Locate the feed plate and number of plates. The vapour pressures of pure benzene and toluene are 1460 and 584 mm Hg respectively. Total pressure is 750 mm Hg.

Solution.

$$\alpha = \frac{\text{vapour pressure of pure benzene}}{\text{vapour pressure of pure toluene}} = \frac{1460}{584} = 2.5$$

$$y = \frac{\alpha x}{[1 + (\alpha - 1)x]}$$

Compute equilibrium data.

x	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
y	0	0.22	0.38	0.52	0.63	0.71	0.79	0.85	0.91	0.96	1.0

Draw the equilibrium curve, diagonal and locate feed, distillate and residue points as shown in Fig. 9.43.

Locate the intercept $\frac{x_D}{[R+1]} = \frac{0.9}{3+1} = 2.25$ and by stepwise construction we can get the number of stages.

No. of stages = 8 (including reboiler) and feed plate is 4

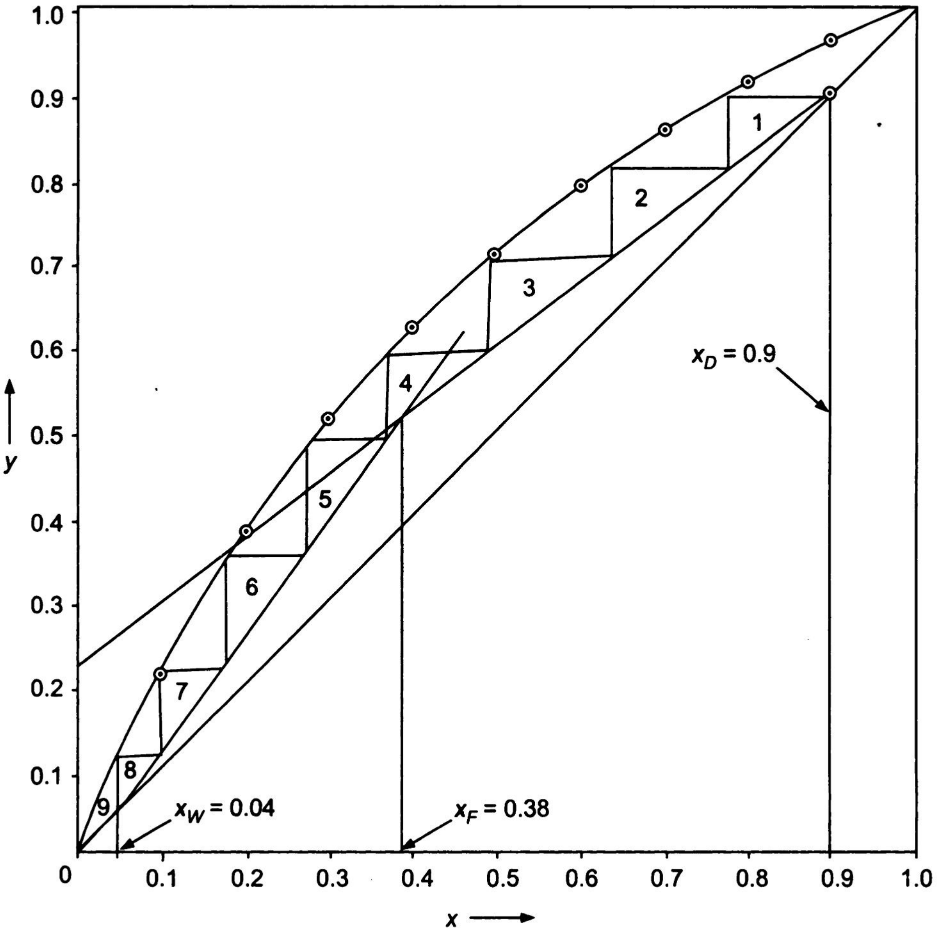

Fig. 9.43 Example 14 McCabe–Thiele method.

15. It is desired to separate a mixture of 50% vapour and 50% saturated liquid in a plate type distillation column. The feed contains 45 mole % A and the top product is to contain 96 mole % A. The bottom product is to contain 5 mole % A. Determine the minimum reflux ratio and the number of theoretical plates needed if a reflux ratio of twice the minimum is used.
Eq. data:

x	0	0.1	0.16	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
y	0	0.215	0.30	0.52	0.625	0.725	0.78	0.89	0.89	0.95	1.0

x, y : mole fraction of A in liquid and vapour phase respectively.

Solution.

$$\left[\frac{x_D}{R_{\text{min}}+1}\right] = 0.33$$

$$R_{\text{min}}+1 = \frac{0.96}{0.33}$$

$$R_{\text{min}} = 1.909$$

$$q = 0.5 \text{ (Fraction of liquid)}$$

$$\text{Slope of } q\text{-line } \left[\frac{q}{q-1}\right] = \frac{0.5}{0.5-1} = -1.0$$

$$R_{\text{actual}} = 2.0 \times R_{\text{min}} = 2.0 \times 1.909 = 3.818$$

$$\left[\frac{y_D}{R_{\text{actual}}+1}\right] = \frac{0.96}{3.818+1} = 0.199$$

Number of stages = 10

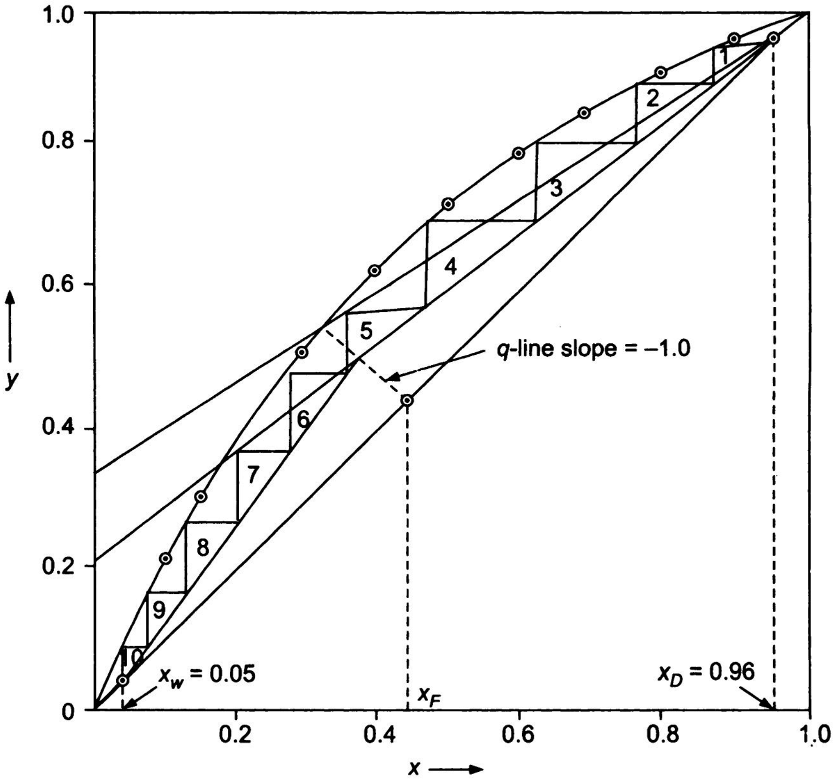

Fig. 9.44 Example 15 McCabe–Thiele method.

16. A fractionating column separates a liquid mixture containing 50 weight % chloroform and 50 weight % carbon disulphide into an overhead product of 94 weight % CS_2 and a bottom product of 95 weight % chloroform. A reflux ratio of twice the minimum will be used and the feed enters at its boiling point. Determine the number of theoretical stages required.
Equilibrium data:

x	0.03	0.06	0.11	0.14	0.26	0.39	0.53	0.66	0.76	0.86	1.0
y	0.08	0.16	0.27	0.33	0.50	0.63	0.71	0.83	0.88	0.93	1.0

x, y mole fraction of carbon disulphide in liquid and vapour phase respectively.

Solution.

Molecular weight of carbon disulphide = 76

Molecular weight of chloroform = 119.5

50 weight % of carbon disulphide,

$$x_F = \frac{\left(\frac{50}{76}\right)}{\left[\frac{50}{76} + \frac{50}{119.5}\right]} = 0.611 \text{ (in mole fraction)}$$

Similarly, the distillate and residue compositions in terms of mole fraction of carbon disulphide are $y_D = 0.961$ and $x_w = 0.076$ respectively.

From graph (Fig. 9.45), $\left(\frac{y_D}{R_{\min} + 1}\right) = 0.49$

$$R_{\min} = 0.96$$

$$R_{\text{act}} = 2 \times R_{\min} = 1.92$$

Therefore, $\left(\frac{y_D}{R_{\text{actual}} + 1}\right) = 0.329 \simeq 0.33$

Number of theoretical stages (from Fig. 9.45) including reboiler = 9

17. A laboratory rectification column is operated at atmospheric pressure and at total reflux, for benzene–chlorobenzene mixture. Samples of liquid from the condenser and reboiler analyze 95 mole percent benzene and 98 mole percent chlorobenzene respectively. Assuming a perfect reboiler, a total condenser, constant molal overflow and no heat loss from the tower, calculate the actual number of plates in the column. The average plate efficiency is 70%. The relative volatility of benzene to chlorobenzene is 4.13.

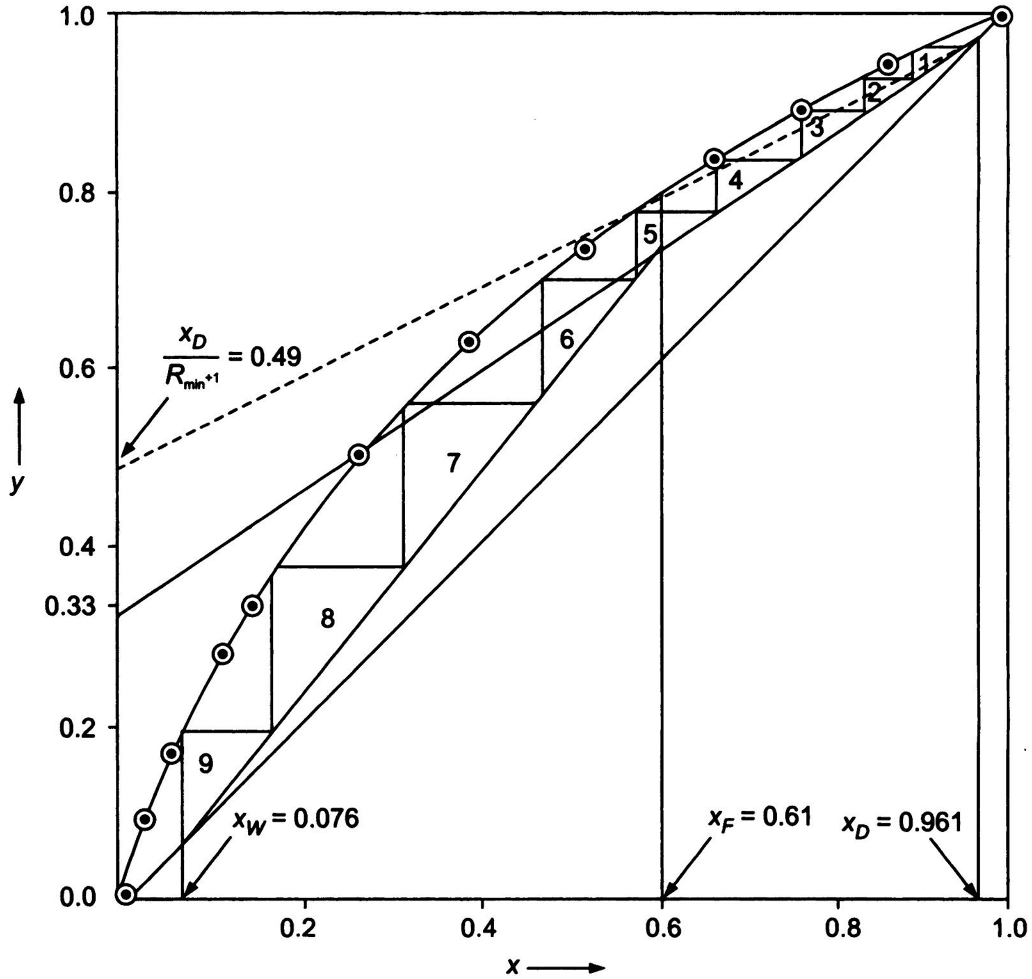

Fig. 9.45 Example 16 McCabe–Thiele method.

Solution.

$$y = \frac{\alpha x}{[1 + (\alpha - 1)x]}$$

Compute equilibrium data.

x	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
y	0	0.31	0.51	0.64	0.73	0.81	0.86	0.91	0.94	0.97	1.0

Draw the equilibrium curve, diagonal and locate feed, distillate and residue points.

By stepwise construction, the number of stages determined is 5.

Hence, the theoretical plates required is 4.

Actual plates required will be $\frac{4}{0.7} = 5.71 \approx 6.$

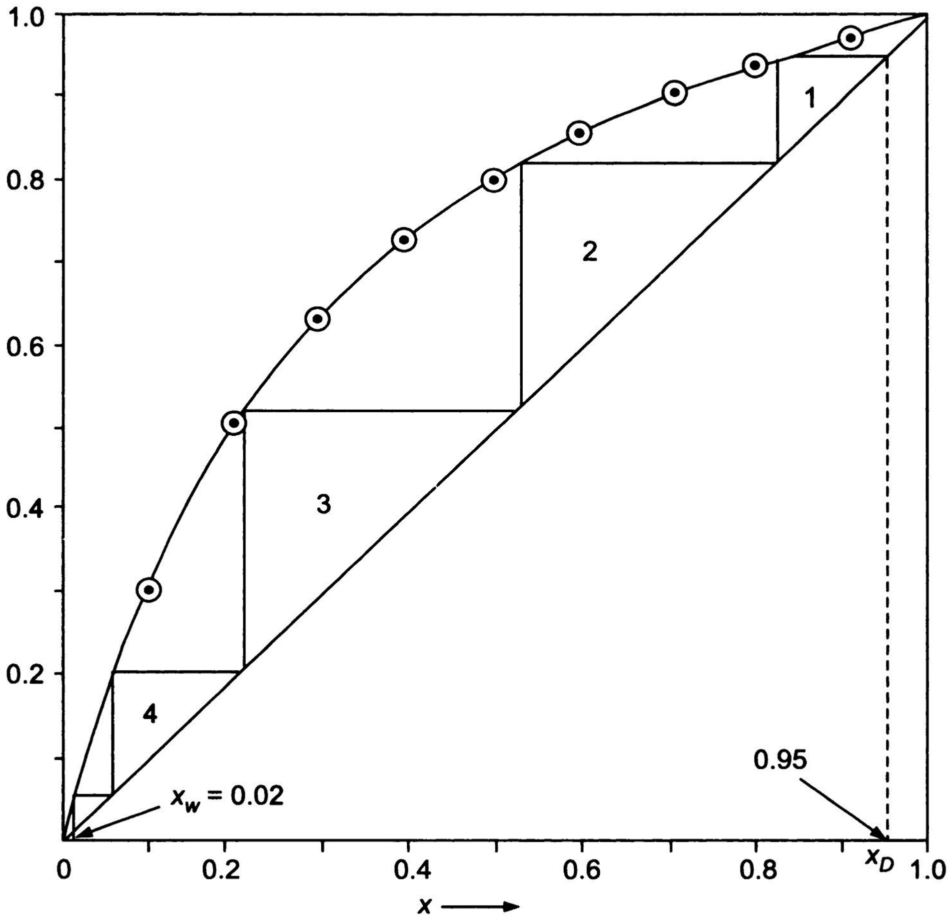

Fig. 9.46 Example 17 McCabe–Thiele method.

Alternatively, we can use the Fenske equation and determine the number of stages.

$$\frac{y_D}{(1-y_D)} = (\alpha)^{N_{P+1}} \frac{x_W}{(1-x_W)}$$

$$\frac{0.95}{(1-0.95)} = (4.13)^{N_{P+1}} \frac{0.02}{(1-0.02)}$$

$$19 = (4.13)^{N_{P+1}} \times 0.02041$$

Hence, $N_P + 1 = 4.82$ stages ≈ 5 stages
Therefore, the theoretical number of plates = 4

Actual plates required will be $\frac{4}{0.7} = 5.71 \approx 6$

(Same as obtained from the graphical procedure)

18. A continuous rectification column is used to separate a binary mixture of A and B. Distillate is produced at a rate of 100 kmol/hr and contains 98 mole % A. The mole fractions of A in the liquid (x) and in the vapour (y) respectively from the two adjacent ideal plates in the enriching section are as follows: