The feed to a continuously operating distillation column is a mixture of carbon disulfide (mole fraction 0.4) in carbon tetrachloride which is 50% vaporized. The total condenser yields a top product having a carbon disulfide mole fraction of 0.95. The partial reboiler produces a bottoms product having a carbon disulfide mole fraction of 0.05. VLE is achieved at each stage.

Solution:

Plot the given VLE data to obtain a y-x graph.

Part 1: Determine minimum reflux

Firstly, need to determine the slope of the q-line on the graph.

$$q = 1 - \frac{V_F}{F}$$

$$q = 1 - 0.5 = 0.5$$

$$\text{Slope of q-line} = \frac{q}{q-1} = \frac{0.5}{0.5-1}$$

$$\text{Slope of q-line} = -1$$

(1 point)

Refer to the Figure 1.

A q-line that has a slope of -1 and passes through the feed composition ($z_F = 0.4$) on the 45˚ line is drawn on the graph.

For the minimum reflux condition, an operating line for the rectifying section that passes through the point $x_D = 0.95$ on the 45˚ line and through the point of intersection of the q-line and the equilibrium curve is drawn.

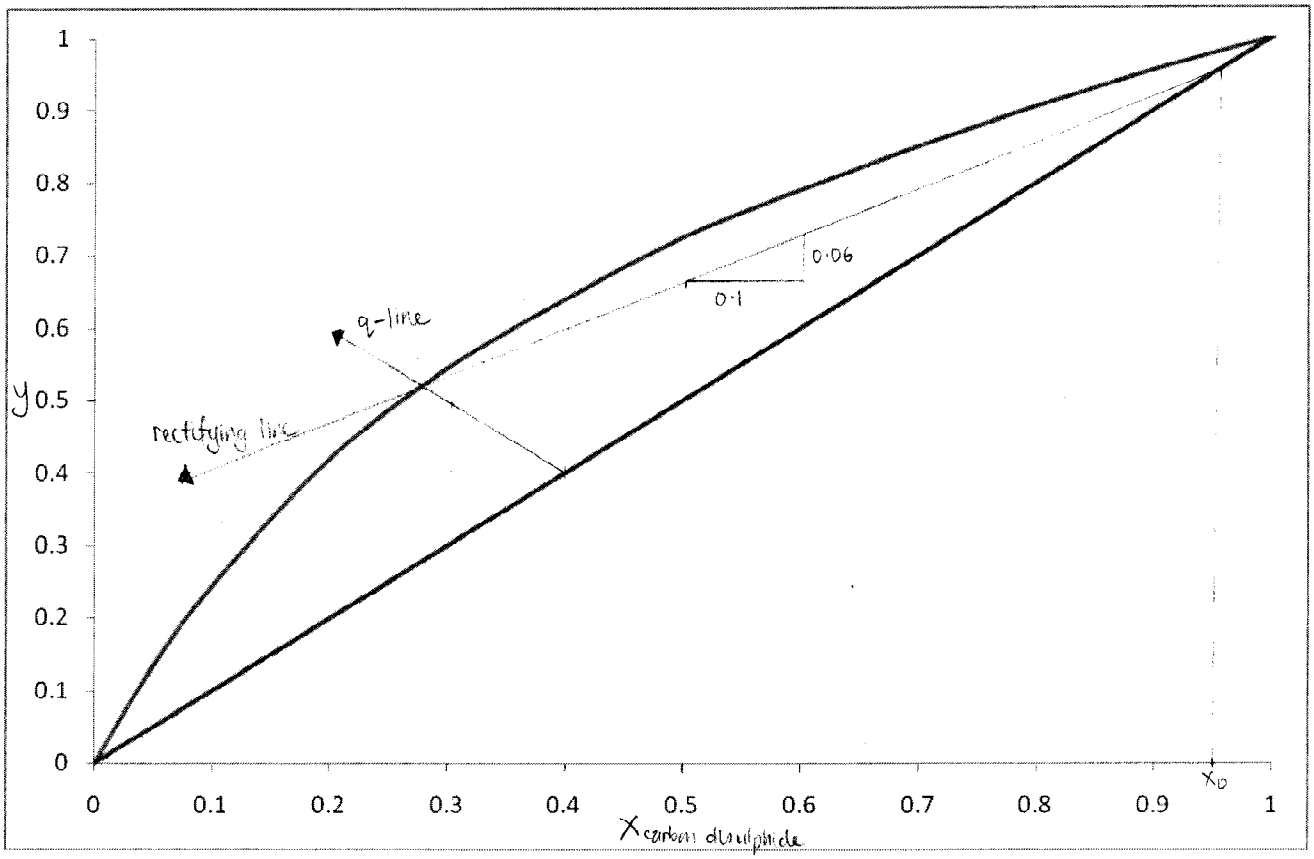
(2 point)

The slope of the operating line is 0.6.

$$\text{Slope of operating line} = \frac{R}{R+1}$$

Solve for minimum reflux ratio R_{min},

$$\boxed{R_{\min} = 1.5}$$ (1 point)


1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
y
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
X carbon disulphide
q-line
rectifying line
0·06
0·1
x_D

Part 2: Determine minimum boilup ratio

This is similar to Part 1. Refer to Figure 2.

A q-line that has a slope of -1 and passes through the feed composition ($z_F = 0.4$) on the 45˚line is drawn on the graph.

For the minimum boilup ratio, an operating line for the stripping section that passes through the point $x_B = 0.05$ on the 45˚line and through the point of intersection of the q-line and the equilibrium curve is drawn.

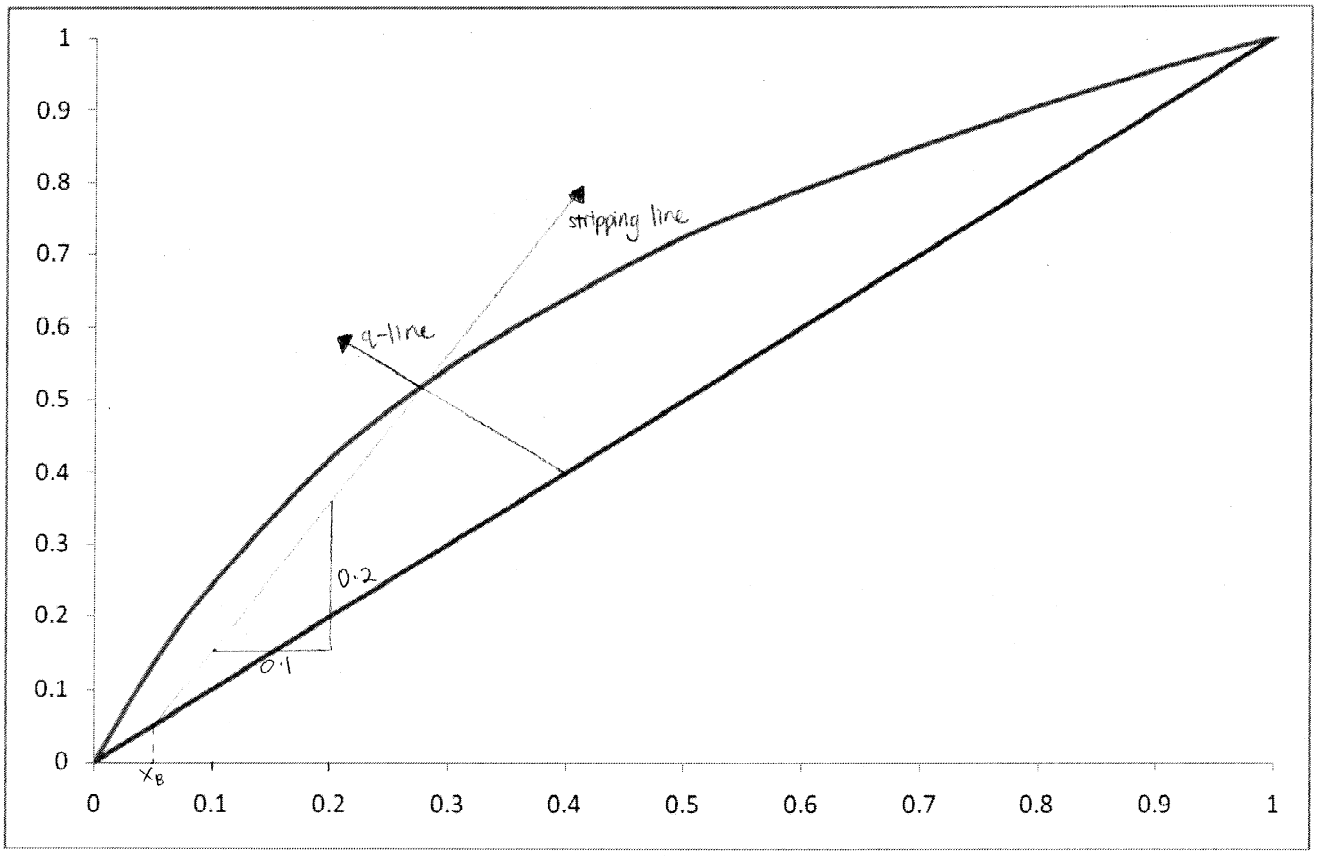
(2 point)

The slope of the operating line is 2.

$$\text{Slope of operating line} = \frac{V_B + 1}{V_B}$$

Solve for minimum boilup ratio,

$$\boxed{V_B = 1}$$ (1 point)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0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
stripping line
q-line
0.2
0.1
x_B

Part 3: Determine minimum number of stages required

To achieve minimum number of stages, the operating lines for the rectifying and stripping sections lie along the 45˚line. This represents the limiting condition for the reflux ratio and boilup ratio.

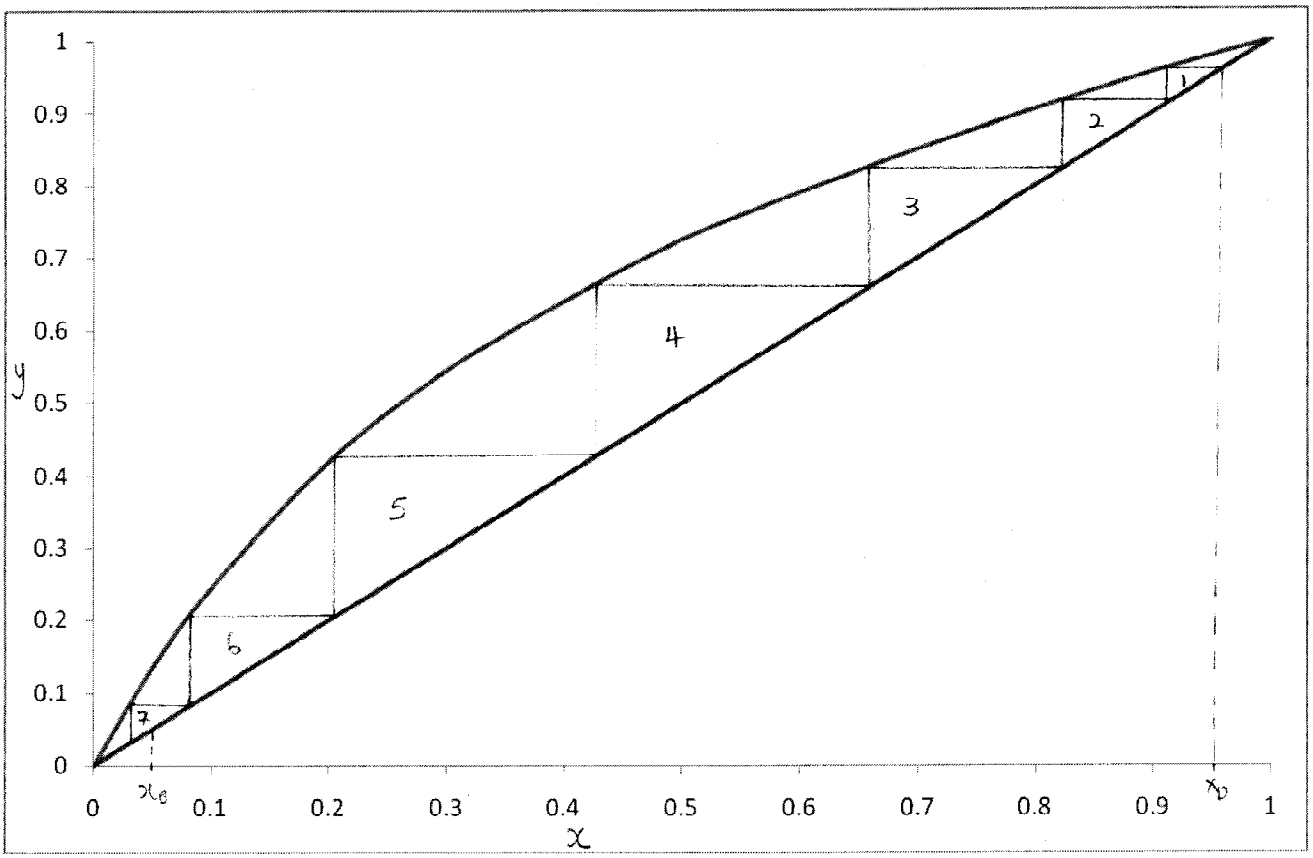
Refer to Figure 3.

The minimum number of stages is obtained by stepping off from the top between the equilibrium curve and the 45˚line.

(2 point)

$$\boxed{N_{\min} = 7}$$

(1 point)


1
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0
y
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0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
x
x_e
x_D
1
2
3
4
5
6
7