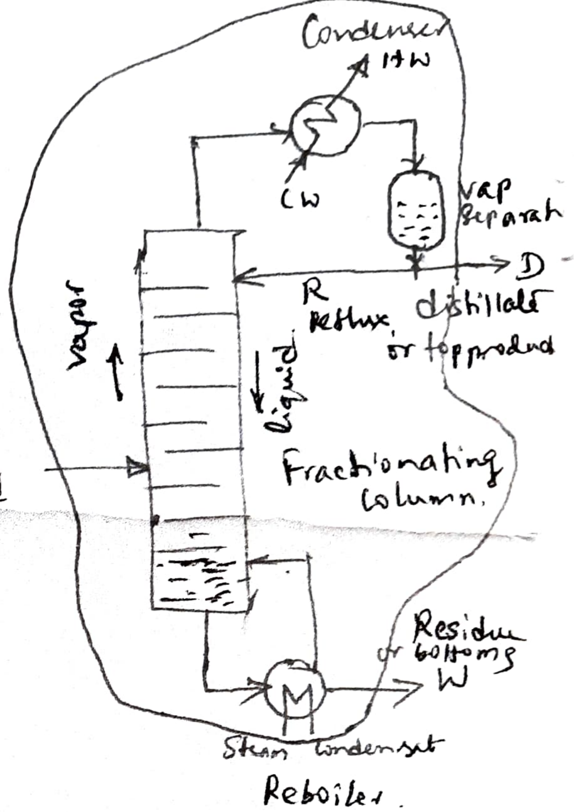
Distillation.

Distillation is an operation in which one or more components of liquid mixtures of two or more components are separated using heat energy. Basically the difference in vapor pressures of different components at the same temperature is responsible for such a separation.



Overall material balance.

$F = D + W$ ——— (1)

F - moles of feed or kg of feed

D - moles of distillate or kg of distillate

W - moles of residue or bottoms or kg of residue

More volatile component (A) balance.

$F \cdot x_F = D \cdot x_d + W \cdot x_w$ ——— (2)

x_F - mole fraction or wt. fraction of MVC in feed

x_d - Mole fraction or wt. fraction of MVC in distillate

x_w - Mole fraction or wt. fraction of MVC in residue.

Feed consist of A and B.

A - more volatile component (MVC)

B - Less volatile component

By solving simultaneous equations (1) and (2) flow rates and compositions can be evaluated.

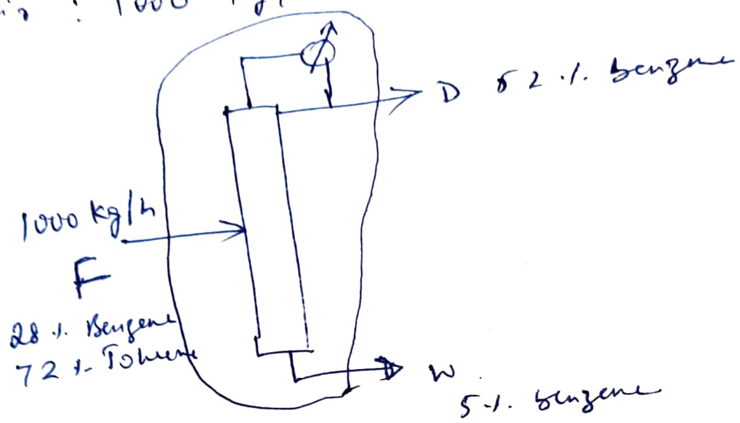
~~Note: if the flow~~

Note: ~~if the flow rates and comp are given in kg~~

For batch process kg or mole, for continuous process kg/h, mol/h

1) The feed to a continuous fractionating column analyses by weight 28% benzene and 72% toluene. The analysis of the distillate shows 52 weight % benzene and 5 weight % benzene was found in the bottom product. Calculate the amount of distillate and bottom product per 1000 kg of feed per hour. Also calculate the percent recovery of benzene

Soln: Basis : 1000 kg/hr of feed to column.



In benzene-toluene mixture, benzene is more volatile component (MVC)

Overall material balance

$F = D + W.$

$1000 = D + W \quad \text{———} \quad (1)$

~~M.V.C. b.~~ benzene (MVC) balance.

$F \cdot x_F = D \cdot x_d + W \cdot x_W$

$1000 \times 0.28 = D(0.52) + W(0.05)$

$280 = 0.52D + 0.05W \quad \text{———} \quad (2)$

Multiply eqn (1) by 0.05

$1000 \times 0.05 = 0.05D + 0.05W.$

$50 = 0.05D + 0.05W$

$230 = 0.47D$

$D = 489.36 \text{ kg/hr}$

$F = D + W$

$1000 = 489.36 + W$

$1000 - 489.36 = W$

$W = 510.64 \text{ kg/hr}$

benzene (MVC) balance or component material.

$F \cdot x_F = D \cdot x_d + W \cdot x_w$.

$58.82 \times 0.5 = D(0.95) + W(0.1)$

$29.41 = 0.95D + 0.1W$. —— (2)

Multiply Eqn 0.1 by 0.95

$55.879 = \cancel{0.95} D + 0.95W$.

$29.41 = \cancel{0.95} D + 0.1W$.

$- \quad - \quad -$

$26.469 = 0.85 W$

$W = 31.14$ ~~kg~~ kmol.

$F = D + W$.

$D = F - W$

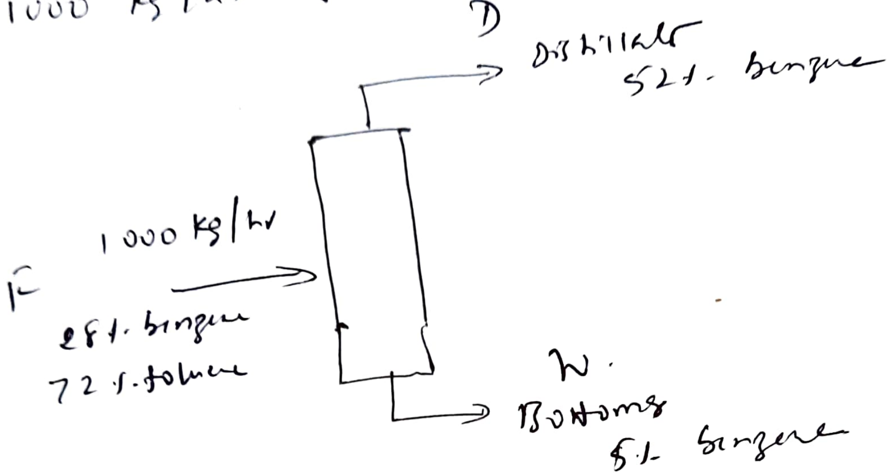
$= 58.82 - 31.14$

$= 27.68$ kmol

Distillation

① The feed to a continuous fractionating column analysis by weight 28% benzene and 72% toluene. The analysis of the distillate shows 52% benzene and 5% benzene was found in the bottom product. Calculate the amount of distillate and bottom product per 1000 kg of feed per hour. Also calculate % recovery of benzene per hour.

Basis : 1000 kg/hr feed to column.



Overall material balance

$F = D + W$ ——— ①

$1000 = D + W$

Component balance

benzene balance

benzene in feed = benzene in distillate + benzene in bottoms

$1000 \times 0.28 = D(0.52) + W(0.05)$

$280 = 0.52D + 0.05W$ ——— ②

Solving eqn ① and ②

$D = 489.4$ kg/hr

$W = 510.6$ kg/hr

Benzene in feed = 280 kg/hr

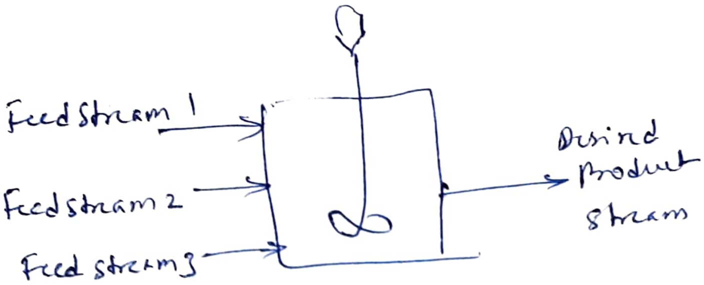
Benzene in distillate = $489.4 \times \cancel{0.05}\ 0.52$

$= 254.49$ kg/hr

% recovery of benzene $= \frac{254.49}{280} \times 100$

$= 90.89\%$

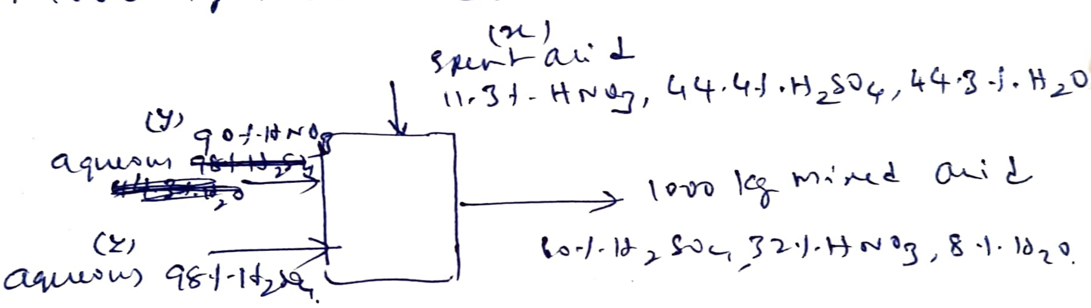
Mixing



This operation is carried out to obtain a product of desired quality by mixing the weak and concentrated streams.

① It is desired to make 1000 kg of mixed acid containing 60% H_2SO_4, 32% HNO_3 and 8% water by blending (i) the spent acid containing 11.3% HNO_3, 44.4% H_2SO_4 and 44.3% H_2O (ii) aqueous 90% HNO_3 and (iii) aqueous 98% H_2SO_4. All percentages are by weight. Calculate the quantities of each of the three acids required for blending.

Basis : 1000 kg mixed acid.



Let x, y, z be the quantities of spent acid, aqueous nitric and aqueous sulphuric acid respectively.

Overall Material balance.

$$x + y + z = 1000 \quad \text{———— (1)}$$

Balance of H_2SO_4.

$$0.444x + 0.98z = 0.6 \times 1000$$

$$0.444x + 0.98z = 600 \quad \text{———— (2)}$$

Balance of HNO_3

$$0.113x + 0.9y = 0.32 \times 1000$$

$$0.113x + 0.9y = 320 \quad \text{———— (3)}$$

$$0.444x + 0.98(1000 - x - y) = 600$$

$$0.444x + 980 - 0.98x - 0.98y = 600$$

$$-0.536x - 0.98y = -380$$

$$0.536x + 0.98y = 380$$

$-0.536x + 0.98y = 380$

$0.113x + 0.9y = 320$

$0.536x + 4.269y = 1517.87$

$3.289y = 1137.8761$

$y = \frac{1137.8761}{3.289} =$

$y = 345.964$ kg

$0.113x + 0.9y = 320$

$0.113x + 0.9 \times 345.964 = 320$

$x = 76.391$ kg

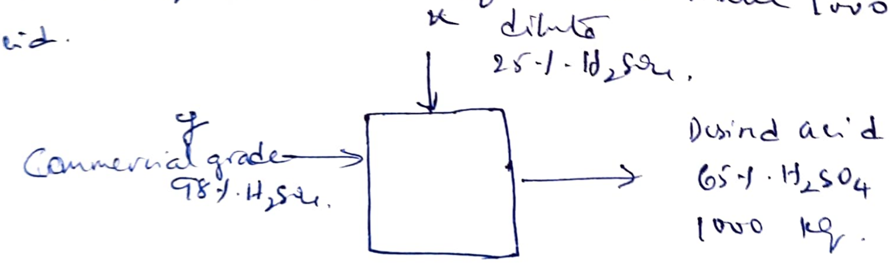
$x + y + z = 1000$

$76.391 + 345.964 + z = 1000$

$z = 1000 - 76.391 - 345.964$

$z = 577.64$ kg

(7) The dilute acid containing 25% H_2SO_4 is concentrated by commercial grade sulphuric acid containing 98% H_2SO_4 to obtain desired acid containing 65% H_2SO_4. Find the quantities of the acids required to make 1000 kg of desired acid.



Basis: 1000 kg desired acid.

x and y be the quantities dilute and commercial grade sulphuric acid respectively

Overall balance

$x + y = 1000$ —— (1)

H_2SO_4 balance

$0.98x + 0.25y = 1000 \times 0.65$

$0.98x + 0.25y = 650$ —— (2)

Solving (1) and (2)

$0.98(1000 - y) + 0.25y = 650$

$980 - 0.98y + 0.25y = 650$

$330 = 0.73y$

$y = \frac{330}{0.73} = 452.05$ kg

$x + y = 1000$

$x = 1000 - 452.05$

$x = 547.94$ kg

$0.98 - 0.25 = 0.73$

$980 - 650 = 330$