Consider one mole of a liquid mixture having $x_f$ mole fraction of more volatile component is fed to a flash distillation unit.

Let 'f' be the fraction of feed that is vaporised & of composition 'y'.

Then $(1-f)$ will be the mole of residual liquid obtained. Let 'x' be the mole fraction of more volatile component in liquid.

Then, a material balance of the more volatile component gives:

Material balance:

$$x_f = f \cdot y + (1-f)\, x \quad \text{——— (1)}$$

$$f \cdot y = -(1-f)x + x_f \quad \text{——— (2)}$$

$$y = -\frac{(1-f)}{f} \cdot x + \frac{x_f}{f} \quad \text{——— (3)}$$

The point of intersection of the operating line & the diagonal $(x=y)$ is:

$$y = -\frac{(1-f)}{f} x + \frac{x_f}{f}$$

$$x = y$$

$$\therefore \quad x = -\frac{(1-f)}{f} x + \frac{x_f}{f}$$

## Distillation:

### Azeotropic Distillation:

This is a special case of multicomponent distillation used for separation of binary mix$^{r}$. which are either difficult or impossible to separate by ordinary fractionation. If the different relative volatility of a binary mix$^{r}$. is very low. Then the continuous rectification of the mix$^{r}$ to give nearly pure product will require high reflux ratio & correspondingly high heat requirement as well as towers of large cross-section & no. of trays.

### Examples of azeotrope distillation:

Consider acetic acid & water solution using butyl acetate as entrainer. The boiling point of acetic acid is 118.1°C & boiling point of $H_2O$ is 100°C. Butyl acetate is slightly soluble in $H_2O$ & consequently forms a hetro azeotrope with it & the boiling point of the azeotrope is 90.2°C. If at least sufficient butyl acetate is added to the top of the distillation column
1. They if forms the azeotrope with all the $H_2O$ in the binary feed mix$^{r}$. The azeotrope may be readily distilled form the high boiling acetic acid which leaves as a residue product the hetro azeotrope on condensation two insoluble liquid layers, one nearly pure water is saturated with ester, the other nearly pure ester saturated with water. The ester

is returns to the top of the column as reflux and is the source of the entrainer in the column. The purce water saturated with ester may be stripped of its small entrainer content by a Steam small column 2. In this way acetic acid is separated from water.

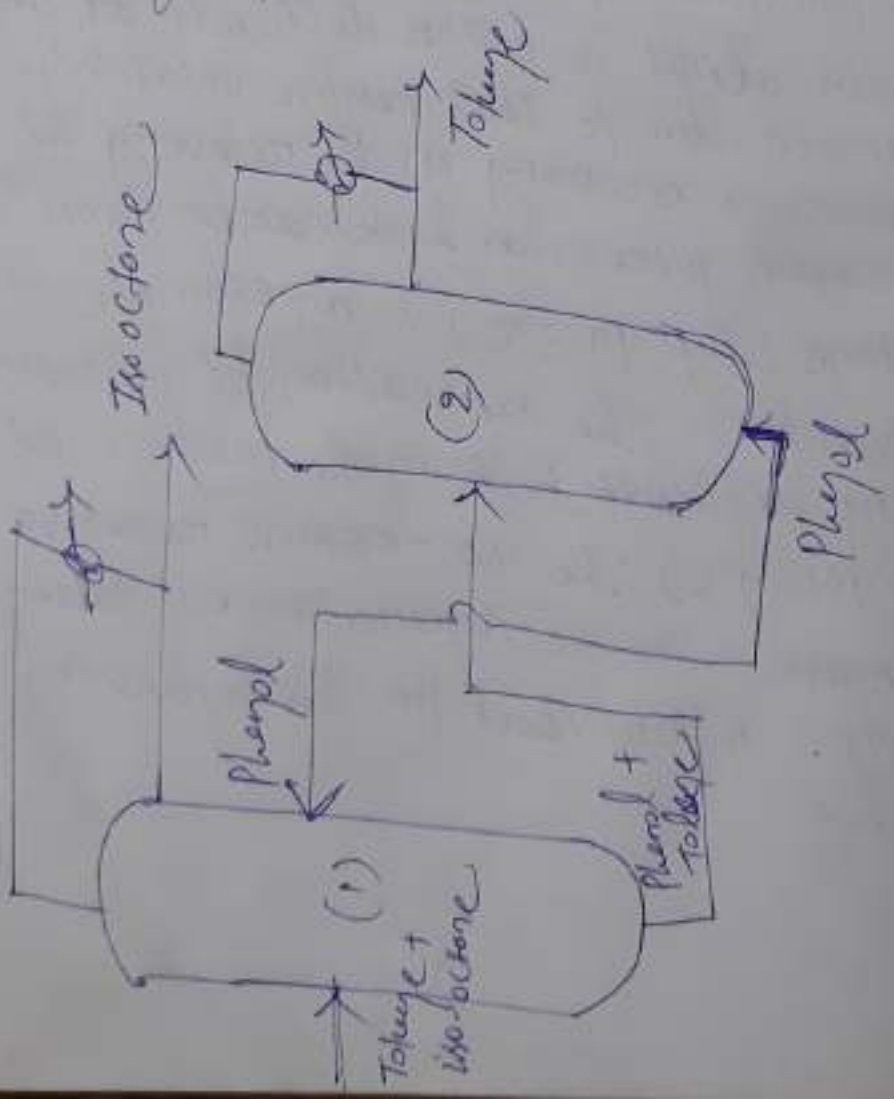
## Extractive Distillation :

This is a multicomponent rectification method similar to purpose to azeotropic distillation to a binary mixt. which is difficult or impossible to separate by ordinary means. means a third component termed as solvent is added which alters the relative volatility of the orogeonal constituents, thus permitting the separation. The added solvent is however low volatility & is itself not appreciably vapourised on the fractionator.

As an example of such an operation consider the process of separation of toulene (b.p 110.8°C) from paraffine hydrocarbons approximetly the same molecular weight is eathere difficult or impossible to separate due to low relative volatility. Such a separation is necessary on the recovery of toulene from certain petroleum hydrocarbon mixt. using iso octane (b.p 99.3°C) is an example of a paraffin hydrocarbon. The separation of isooctane toluene is very difficult but in the presence of phenol. (b.p 181.4°C) The iso-octane relative volatility increase. So the separation of toluene is relative easily. A flow sheet for this separation is shown in fig.

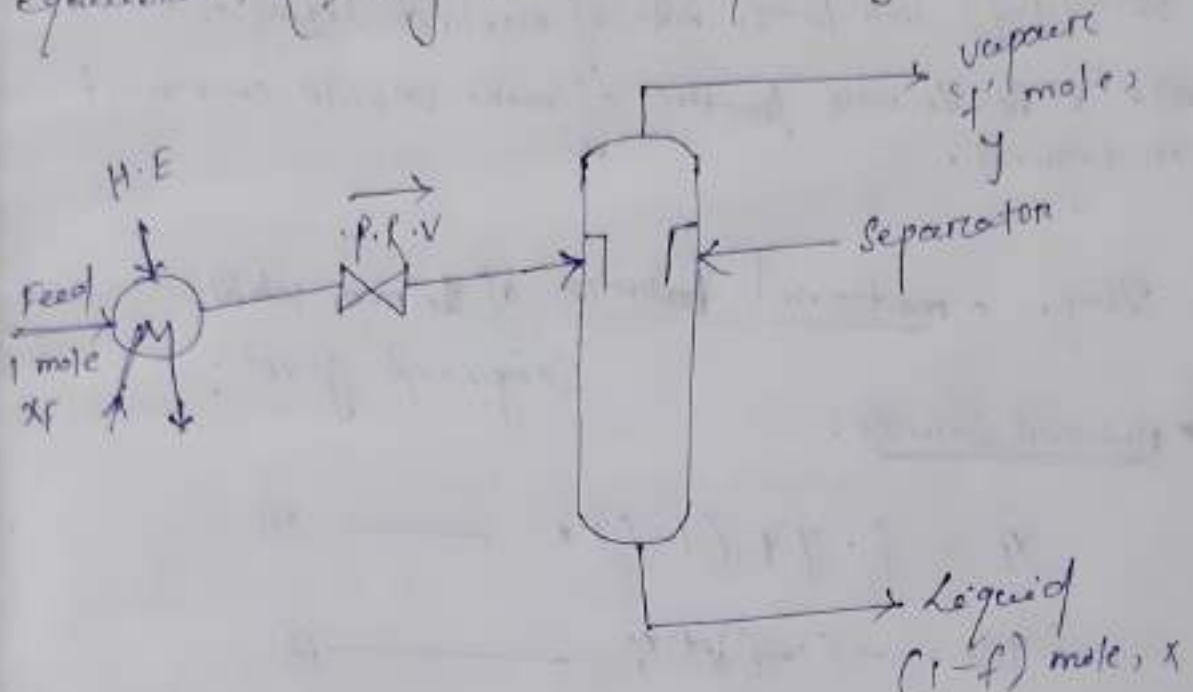
The binary mix°. is introduced more or less centrally into the extractive distillation tower (1). A Phenol as a solvent is introduced near the top. under this condition iso-octane is readily distilled as an over head product. while toluene & phenol are removed as residue. B.P of Phenol is very high due to this b.p. It is not appear in the over head product.

The solvent recovery section is the tower serve to separate the phenol from the iso-octane. The residue from the tower must be rectified in the auxiliary tower (2) to separate toluene from phenol which is re-cycled.



## Flash distillation :-

Flash distillation is normally carried out in a continuous manner. In this method, a liquid mixt. is partially vaporised, the vapour & liquid are allowed to attain equilibrium & finally withdrawn separately.




Feed is heated in a tubular heat exchanger. The hot liquid mixt. is then fed to a separator via pressure reducing valve whereby pressure is reduced & the vapour is formed at the expense of liquid adiabatically. The liquid is withdrawn from the bottom of the separator and the equi. vapour leaves the separator from the top which is then liquefied in a condenser. Flash distillation is commonly used in petroleum industry, handling multi component systems in the pipe stills.

$y \cdot f = -x + x \cdot f + x_f$

$\therefore x = x_f$

$y = x_f$

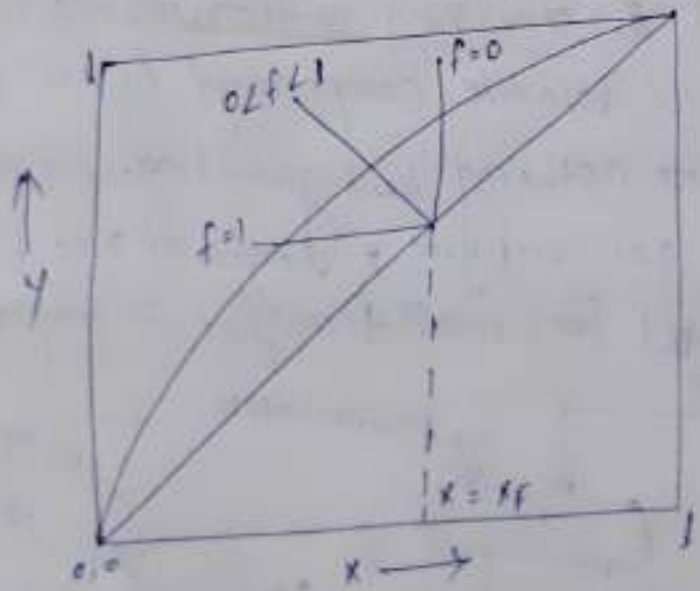
for $f = 1$, feed totaly vaporised (feed 100 mole percent vapourised)

$$\text{Slope} = -\frac{(1-f)}{f} = 0$$

∴ hence operating line is parallel to x-axis through point $(x_f, x_f)$ on the diagonal.

for $f = 0$, — no feed is vapourised

Slope = $\infty$ ∴ the operating line will be parallel to y-axis through a point $(x_f, x_f)$ on the diagonal.



## Steam Distillation :-

This technique is used for separating substances which are immiscible with water, volatile on steam & having high vapour pressure at the boiling temperature of water.

Consider two immiscible liquids. In the mixture one liquid cannot mix the properties of the other. So each liquid behaves as if the other is not present. Therefore each liquid will show it's on vapour pressure but the sum of the vapour pressures will be much higher than the vapour pressures of liquids. Hence the mixture of two immiscible liquid will boil at a lower temperature than the normal boiling point. So this method can be used for purifying liquids with very high boiling point.

ex- Naphthalene.

If water is used as one of the immiscible liquids the method is called Steam distillation. It is also used for purifying liquids which decomposes at their normal boiling points. eg ex- Glycerol.

Applications :

(i) Steam distillation is used to separate intermediate or final products during the synthesis of complex organic compounds.

(ii) It is also widely used in petroleum refineries & petrochemical plants.

(iii) It is used for separating fatty acids from mixtures & for treating crude products such as tall oils to extract & separate fatty acids, soaps & other commercially variable organic compound.

(iv) Steam distillation is used for separating organic compounds from plant parts e.g. Lemon grass oil, Eucalyptus oil etc.