LAB 3: Two Component Systems Containing Liquid Phases (Part 2)

Objective:

Determine the amount of each component in each phase in a water/phenol system prepared at certain concentration at certain temperature.

Background:

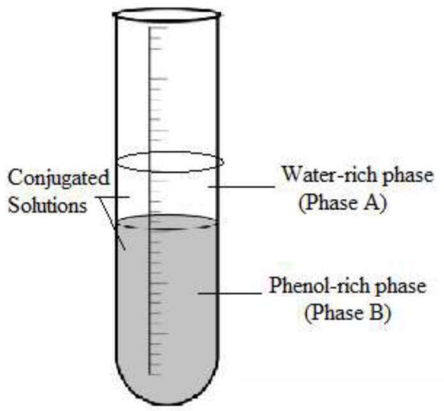
In water-phenol system, at certain temperature, along the tie line, the system appears as 2 phase system existing together in equilibrium.

One can determine the full composition of a system by determining the limits of tie line.

Tie line is the line drawn across the region of two-phase system in a phase diagram at certain temperature. (See figure in next page for clarification)

For 2 component liquid systems:

- The tie line is parallel to x-axis
- There are different tie lines for different temperatures. As the temperature increases, tie lines become shorter.
- Along the tie line at certain temperature, all systems appear as two-phase systems existing together in equilibrium known as ***conjugate solutions or phases*** with constant composition (concentration). The conjugated phases are composed of an upper layer which will be water-rich phase (phase A), and the lower layer will be phenol-rich phase (phase B).



What is the importance of determining the tie line?

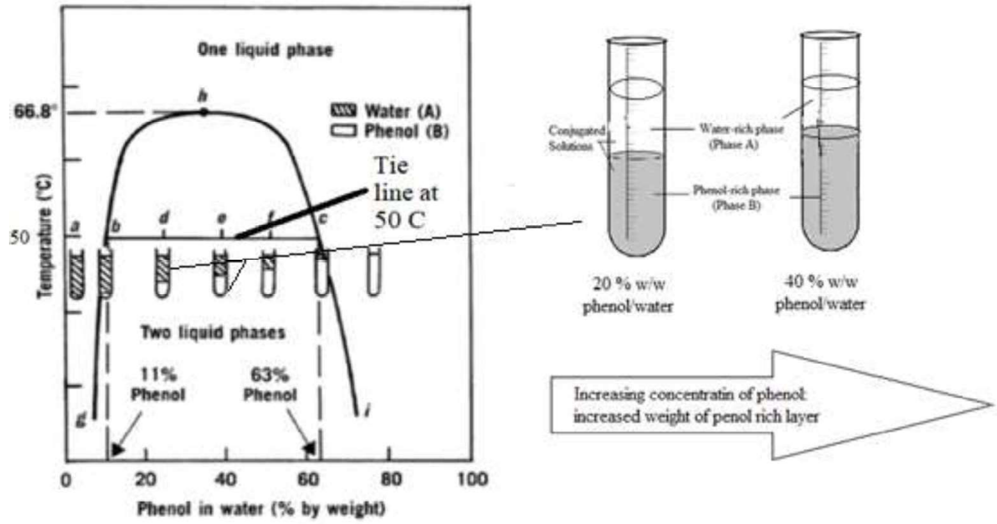
By determining the tie line at certain temperature, we will be able to determine the full composition of phases for all systems along the tie line (for all systems lying on the tie line) (i.e., determine the weight of each phase, % of each component and weight of each component in each phase).

This can be done by keeping in mind the following two points:

A. The ***mass ratio*** (ratio by weight of phase A to phase B) is changing along the tie line.

The weight of phenol rich phase (phase B) increases by increasing the concentration of phenol in the system while the weight of water-rich phase (phase A) will decrease (see figure below).

Therefore, mass ratio of a certain two-phase system will depend on its position along the tie line. By determining the mass ratio, we will be able find out the weight of each layer.



B. The concentration of phenol in each layer is constant. This can be determined as follows:

The % of phenol representing the beginning and ending limits of tie line at certain temperature will enable us to determine the composition of each phase in all systems lying on the tie line, existing together in equilibrium:

- The starting number of tie line represents % phenol in phase A (water-rich phase)
- The ending number of tie line represents % phenol in phase B (phenol-rich phase)

For example, at 25° C, the tie line is 7-70% w/w phenol in water, thus:
% phenol in phase A (upper phase) = 7%
% phenol in phase B (lower phase) = 70%

This will represent the composition (concentration of phenol) in each phase for any system lying on tie line, regardless the concentration of phenol/water in the whole system.

In other words: for phenol/water system at 25°C, along the tie line, at any concentration of phenol/water system (whether it is 20 %, 30% or 55%, etc.), the concentration of phenol in upper layer is always 7% and the concentration of phenol in lower layer is always 70 %.

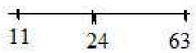
By knowing the mass ratio, % phenol in the system, % phenol in each layer, we can simply determine the weight (gm) of phenol (as well as water) in each layer, as explained in the following example.

Example: A system weighs 80 gm pf phenol in water at 50 °C, the concentration of phenol in this system is 24% w/w. what will be:

a. **Tie line at 50° C**
b. **Mass ratio**
c. **% of phenol in each phase**
d. **Amount of phenol and water in each phase**

Answer:

a. Tie line is 11-63 % w/w phenol/water (this is determined from phase diagram of phenol in water system)



b. Mass ratio = $\frac{wt\ of\ phase\ A}{wt\ of\ phase\ B} = \frac{63-24}{24-11} = \frac{39}{13} = \frac{3}{1}$

c. % phenol in phase A = 11 % w/w, % phenol in phase B = 63 % w/w

d. To find amount of phenol in each phase, we must first find the total weight of phases

Total parts = parts of phase A + parts of phase B = 3 + 1 = 4 parts
Total weight = weight of phase A + weight of phase B = 80 gm
So:

Weight of phase A	**Weight of phase B**
Parts — Weight (gm) 4 parts — 80 gm 3 parts — x gm	Parts — Weight (gm) 4 parts — 80 gm 1 parts — x gm
Thus: x = 60 gm	Thus: x = 20 gm
Weight of phenol in phase A	**Weight of phenol in phase B**
11 — 100 x — 60	63 — 100 x — 20
Thus: x = 6.6 gm phenol	Thus: x = 12.6 gm phenol
Weight of water in phase A	**Weight of water in phase B**
Weight of water in phase A = 60-6.6 = 53.4 gm	Weight of water in phase B = 20- 12.6 = 7.4 gm

To check out: % phenol in the system = $\frac{weight\ of\ phenol\ in\ phase\ A+B}{Total\ weight}\ x\ 100 = \frac{6.6+12.6}{80}\ x\ 100$ = 24 %