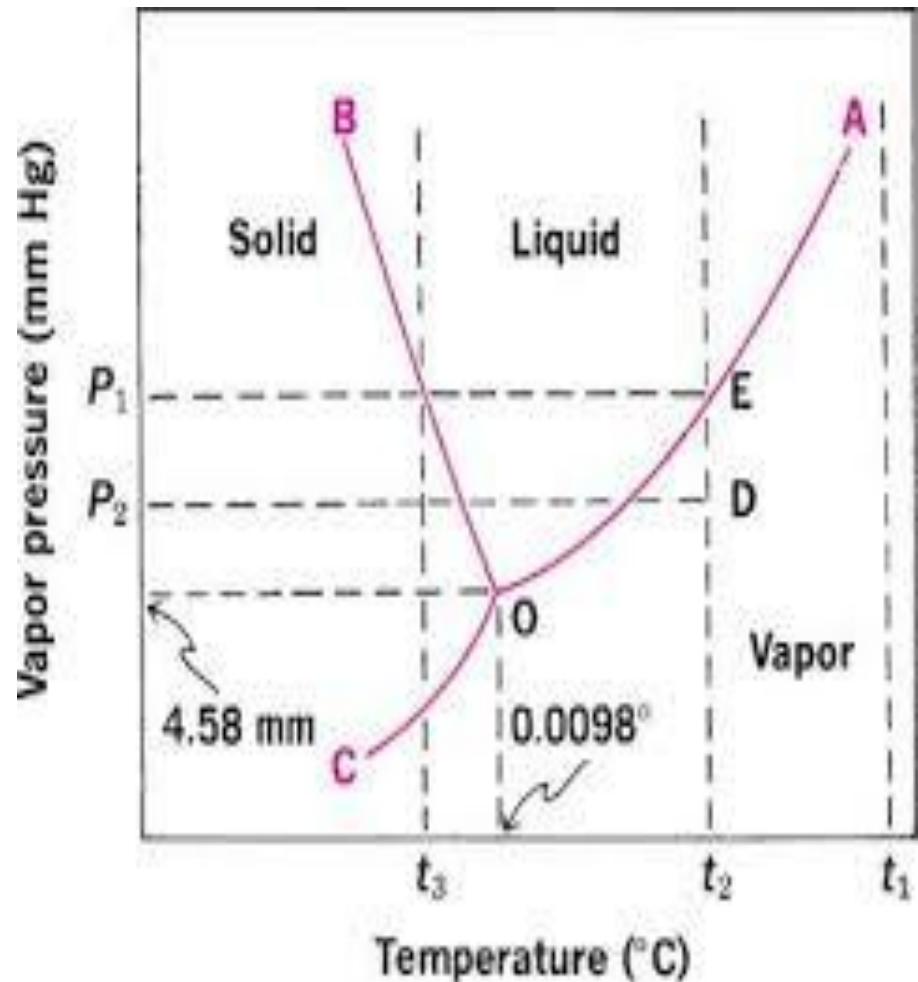
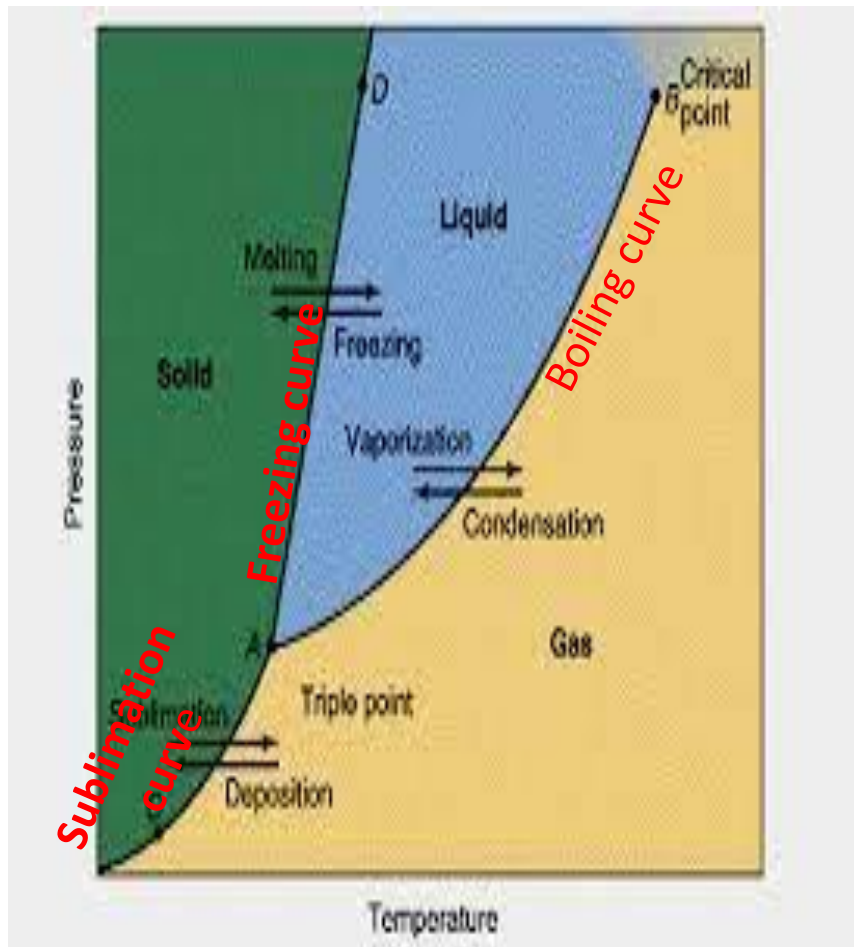


**Phase equilibria**  
**and**  
**Phase rule**

# Phase equilibria of one component system ( $\text{H}_2\text{O}$ )



# Phase rule

- Phase rule is the effect of least number of independent variables (**P, T, X**) upon the various phases (**S, L, G**).
- The phase rule expressed as:  **$F=C-P+2$**
- **F**: number of degrees of freedom
- **C**: number of components
- **P**: number of phase
- **2**: T and **P**

# 1- one component system (H<sub>2</sub>O)

$$C=1$$

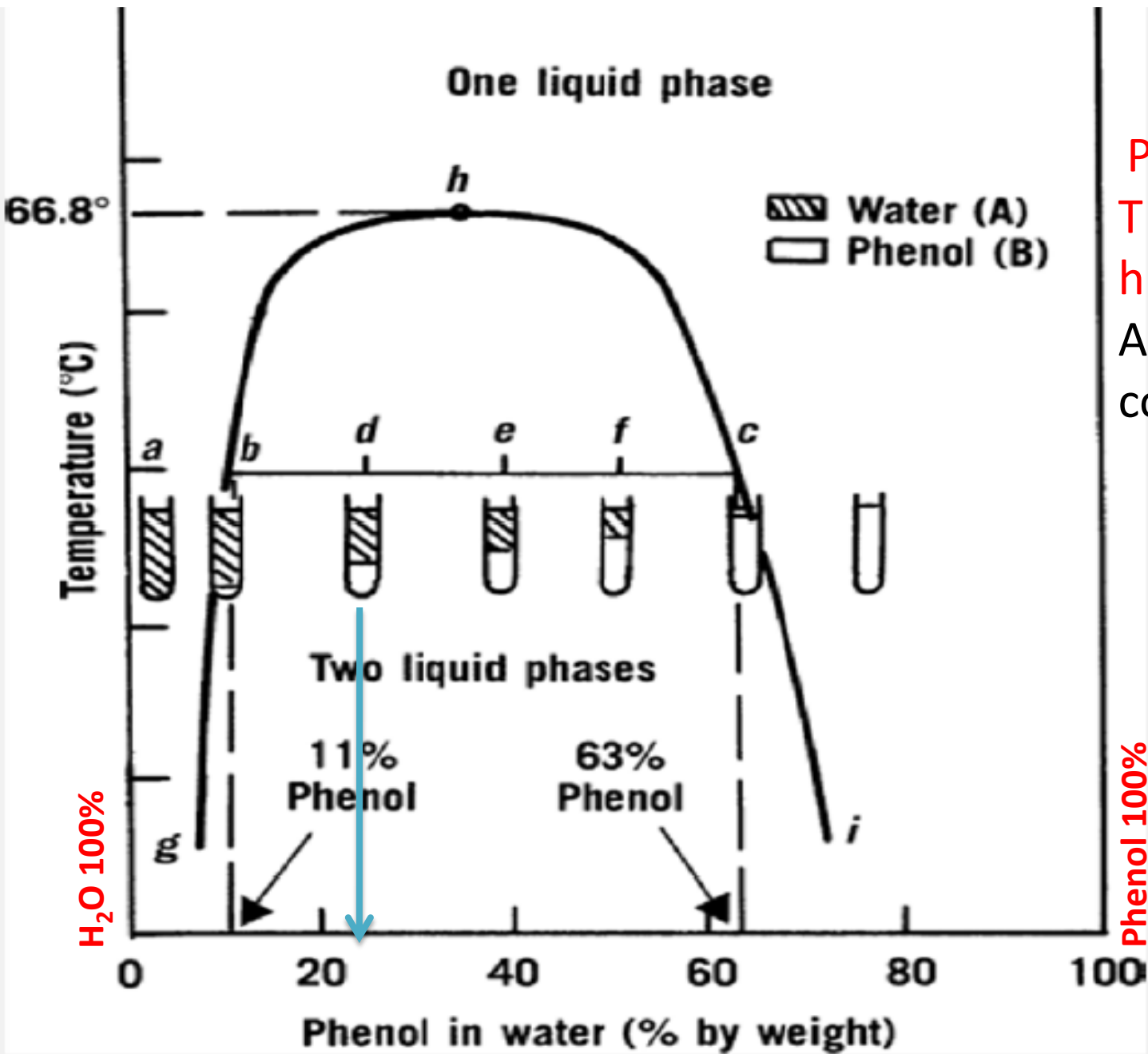
system	phase	$F=C-P+2$	Variables
G or L or S	1	$F = (1-1+2) = 2$	P and T
Equilibrium curve G-L L-S G-S	2	$F = (1-2+2) = 1$	P or T
Equilibrium point G-L-S	3	$F = (1-3+2) = 0$	No variables <b>P = 4.58 mmHg</b> <b>T = 0.0098 °C</b>

# Two component system (phenol-water)

- (L-S) phases partially miscible
- The miscibility of system depend on the temperature  $T$  and % of composition at constant pressure  $P=1$  atm.

# Degree of freedom of two component system

- $F = C - P + 2$
- For **one** L phase:  $C=2$ ,  $P=1$
- $F = 2 - 1 + 2 = 3$ , (T, %, **P**)
- For two L phases:  $C=2$ ,  $P=2$
- $F = 2 - 2 + 2 = 2$ , (T, %) at this region **P** is fixed at 760 mmHg



P is constant  
 T and % are variable  
 h: critical solution  
 Above this T all % completely miscible

H<sub>2</sub>O 100%

Phenol 100%

- The **composition** of H<sub>2</sub>O, phenol in the region of **two liquid** phases at temperature **T** expressed by the relation-ship:
- At d point (weight H<sub>2</sub>O/weight phenol)= dc/bd
- = (63-23)/ (23-11) = (40/12) H<sub>2</sub>O/phenol

# Other partially miscible system

With two critical point  
Upper and lower T

With lower critical T

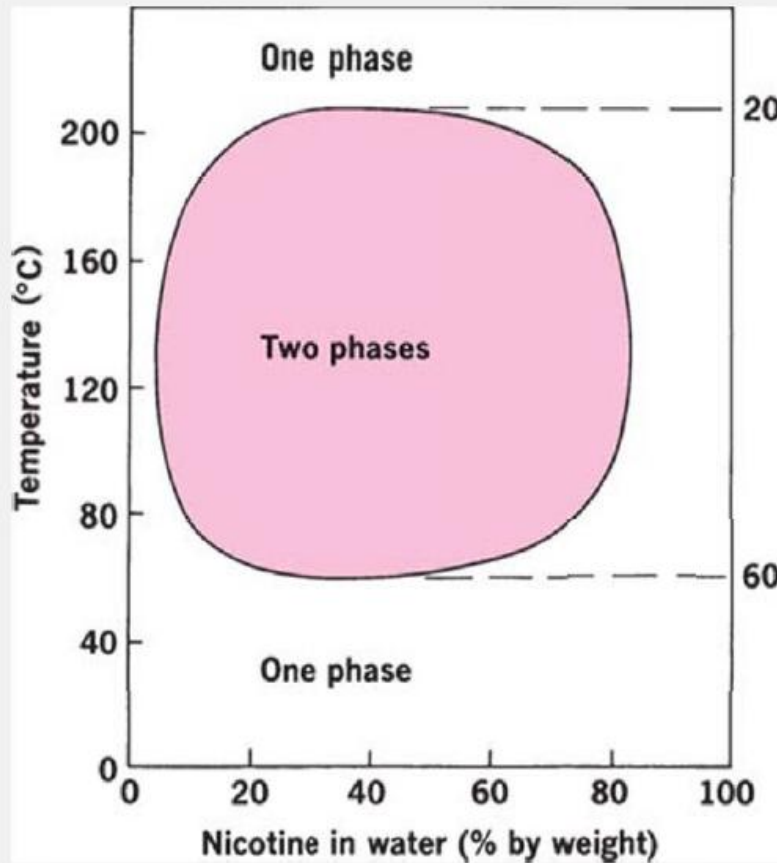


Fig. 2-25. Nicotine-water system showing upper and lower consolute temperatures.

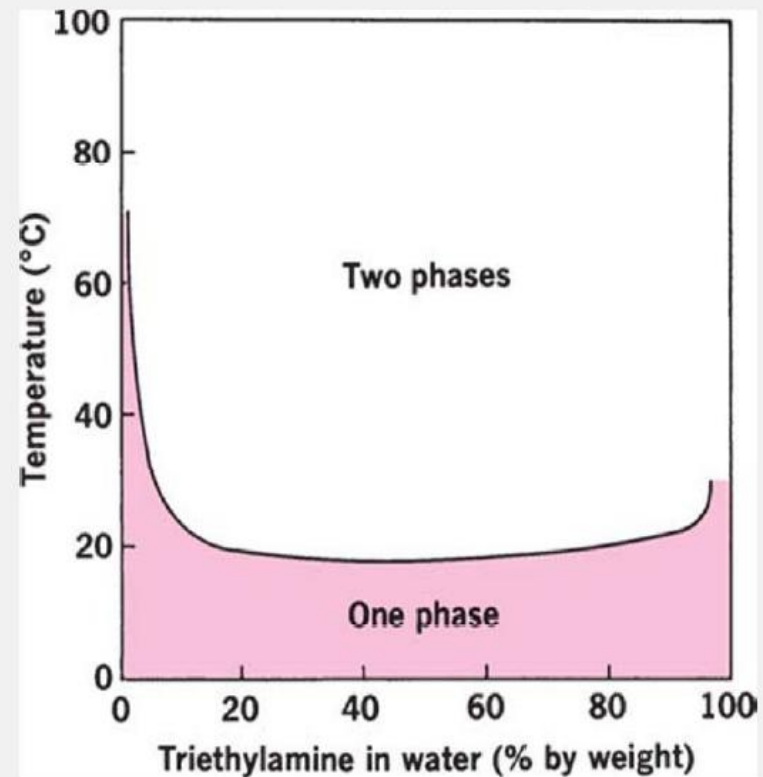


Fig. 2-24. Phase diagram for the system triethylamine-water showing lower consolute temperature.

# Three components system

- For one phase system (completely miscible)

The degree of freedom :  $C=3$ ,  $P=1$

$F = C - P + 2 = 3 - 1 + 2 = 4$  four degree of freedom

$(T, P, X_1, X_2)$

Because  $X_3$  fixed by  $X_1$  and  $X_2$

$$1 = X_1 + X_2 + X_3, \quad X_3 = 1 - (X_1 + X_2)$$

At constant  $p$  and  $T$   $F=2$ ,  $X_1$  and  $X_2$

# Triangular diagram for three component system

The point **E** composition

**C**=63%

**H**=17%

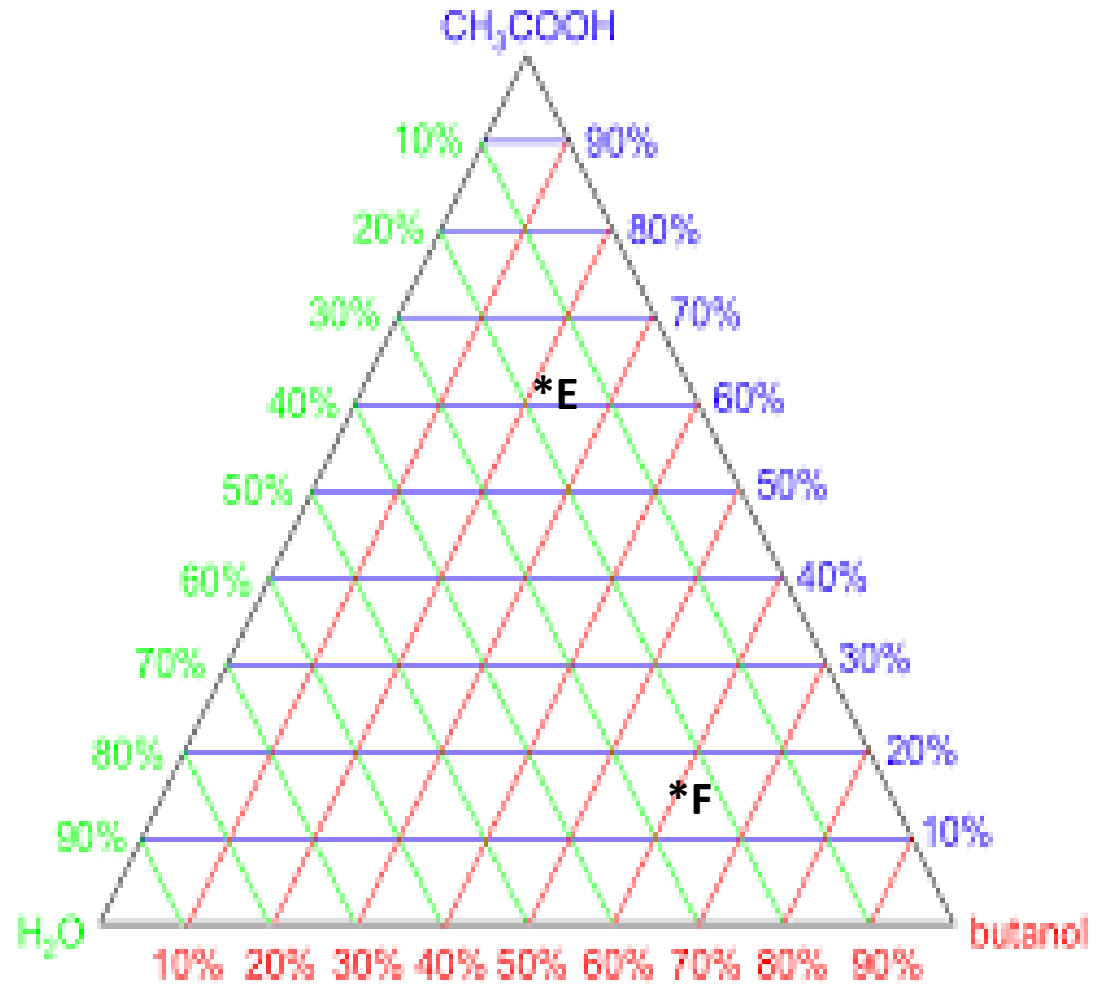
**B**=100-(17+63) = 20%

The point **F** composition

**C**=15%

**H**=25%

**B**=100-(15+25)=60%



# T effect on the miscibility of ternary (3) system

System of three liquids, one pair of which is partially miscible

Alcohol with ( $C_6H_6 + H_2O$ )

T effect can be illustrate by following diagrams

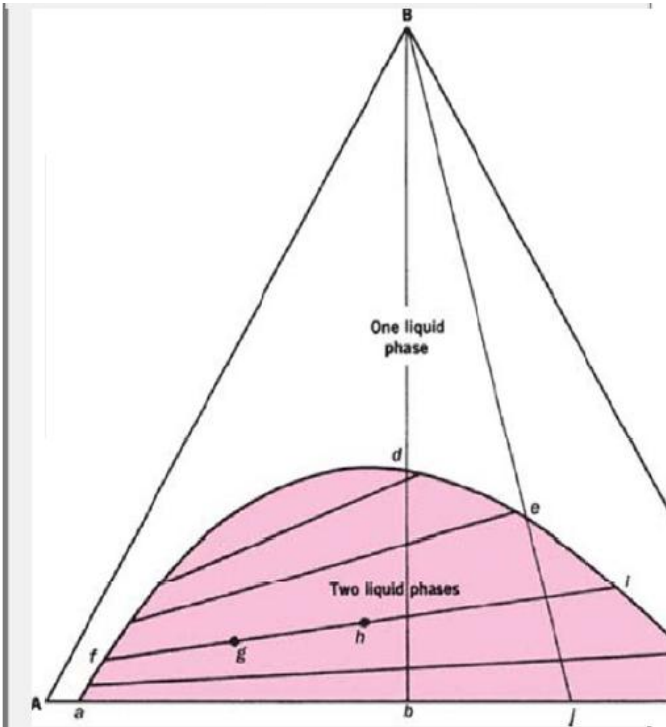


Fig. 2-28. A system of three liquids, one pair of which is partially miscible.

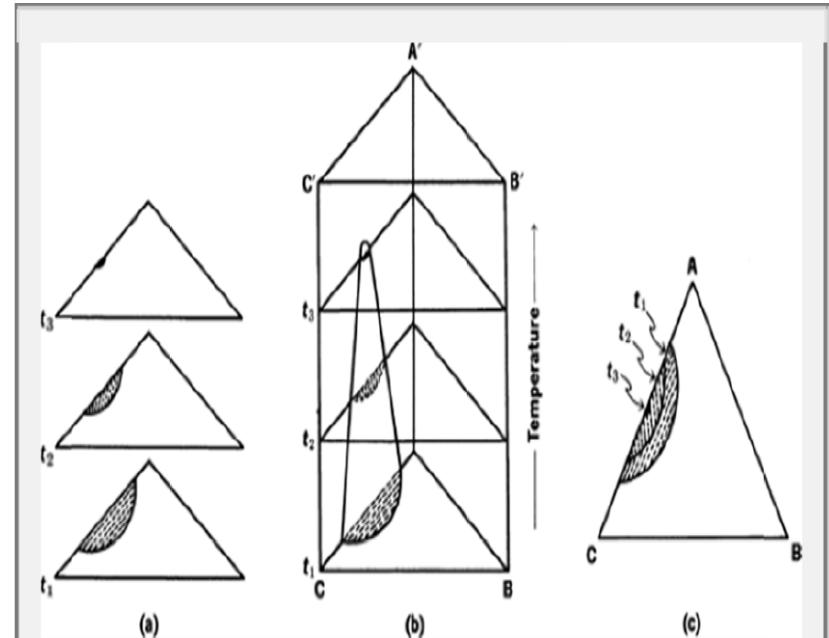


Fig. 2-29. Alterations of the binodal curves with changes in temperature. (a) Curves on the triangular diagrams at temperatures  $t_1$ ,  $t_2$ , and  $t_3$ . (b) The three-dimensional arrangement of the diagrams in the order of increasing temperature. (c) The view one would obtain by looking down from the top of (b).