The Stabilities of phase

What is a phase?

- A phase is a form of matter that is uniform throughout in chemical composition and physical state

Example

Fig 1. White phosphorus

Fig 2.Black phosphorus

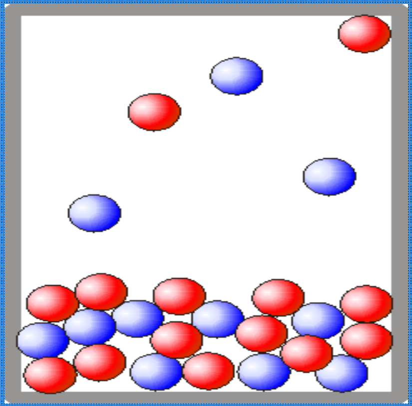


Fig 3. Liquid phase

A phase transition is the spontaneous conversion of one phase into another phase,occurs at a characteristic temperature for a given presure

Example

At 1 atm

Below 0^0C

Ice

Above 0^0C

Liquid water

Fig 4. The example of phase transition

The transition **temperature, T_{trs},** is the temperature at which the two phase are in equilibrium and the Gibbs energy is minimized at the prevailing presure

Example

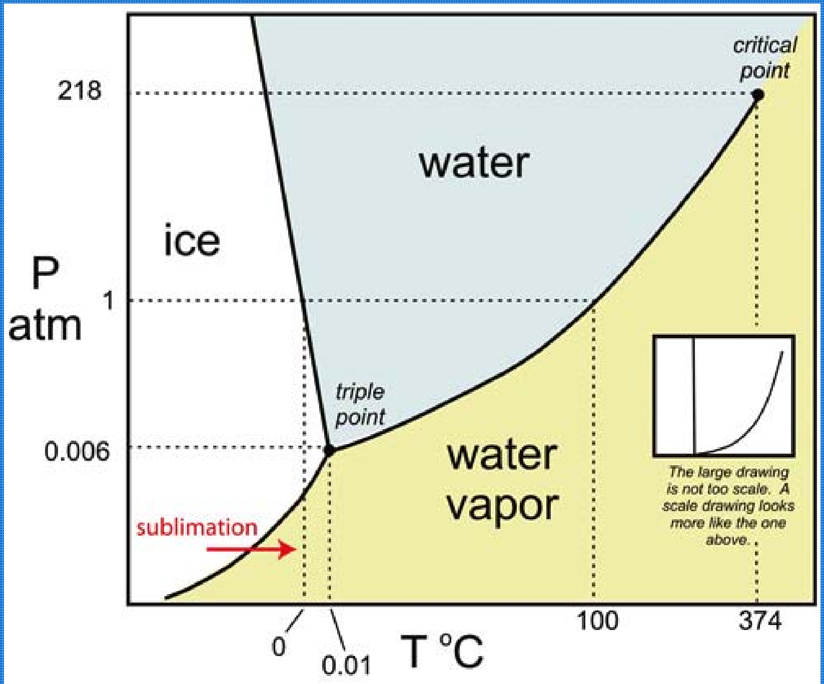
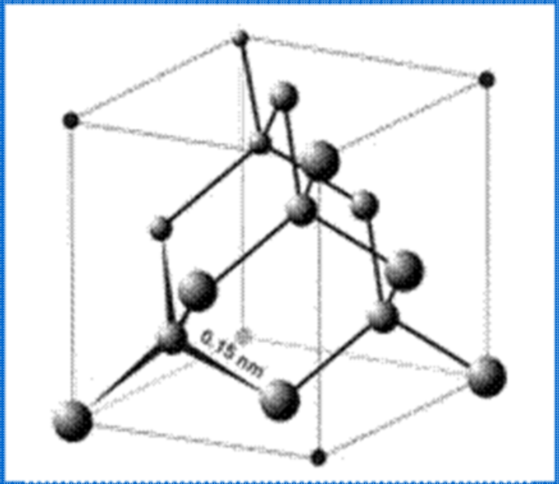


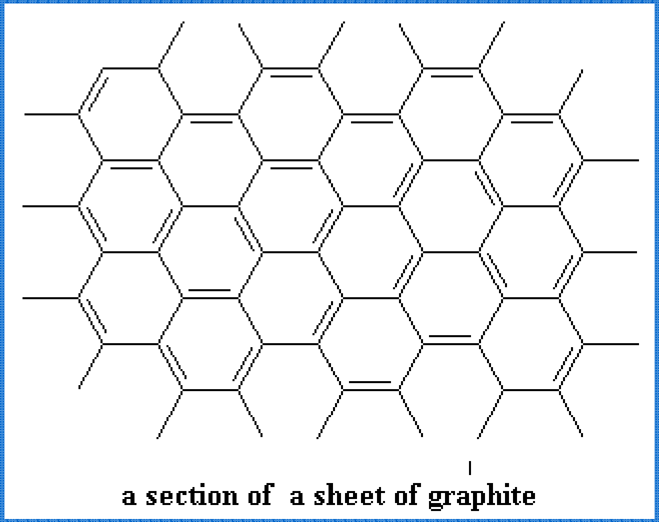
Fig 5. The transition temperature of water

A metastable phase is a thermodynamically unstable phase that persists because the transition is kinetically hindered

Example



Diamond



Graphite

Fig 6. Metastable phase of carbon

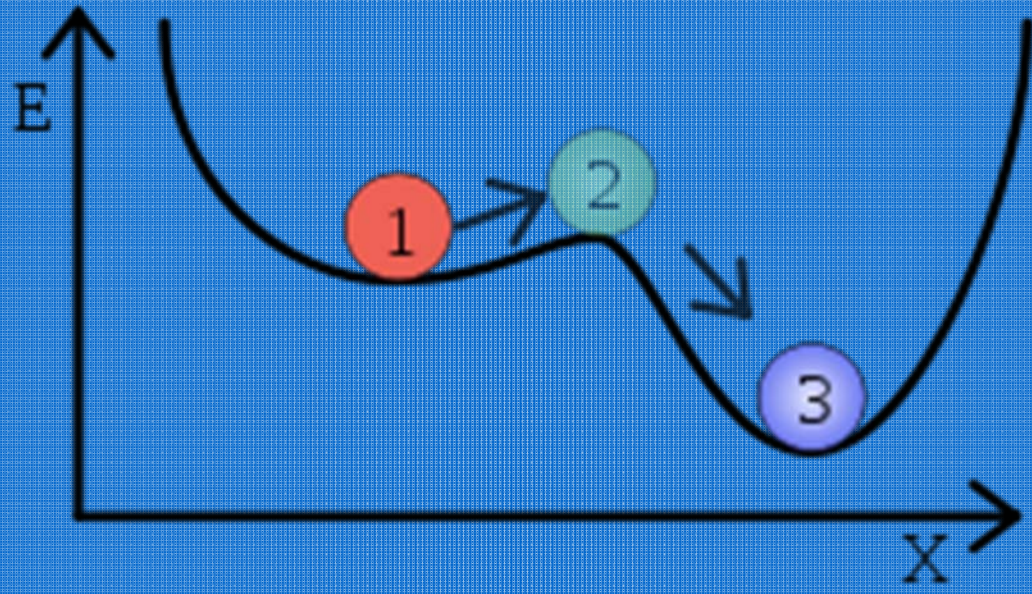


Fig 7. A metastable systems diagram

Phase boundaries

- A phase diagram is a diagram show the regions of pressure and temperature at which its various phase are thermodynamically stable

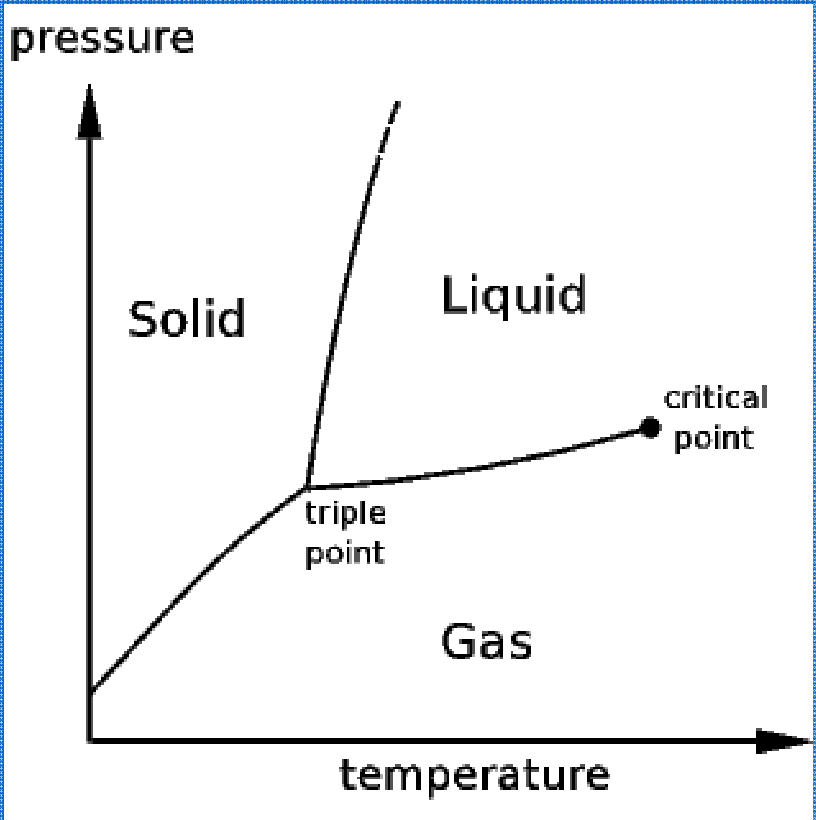


Fig 8. A typical phase diagrams

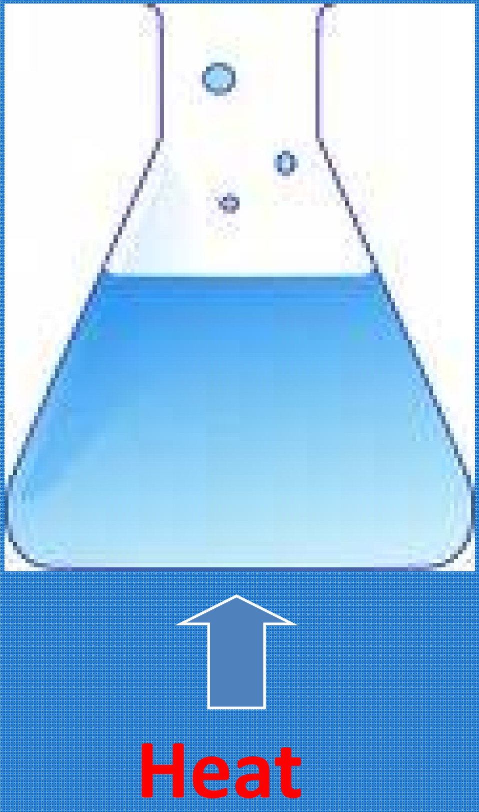
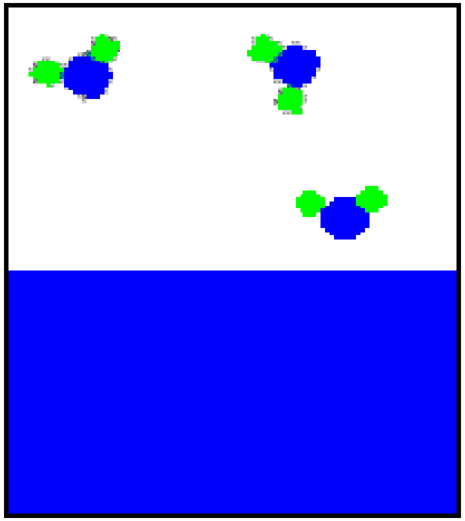


Fig 10. The boiling process

- The temperature at which the vapour pressure of a liquid is equal to the external pressure is called the boiling temperature

With a lid, the mole-
cules are trapped in
the container and so
there is no net loss of
water



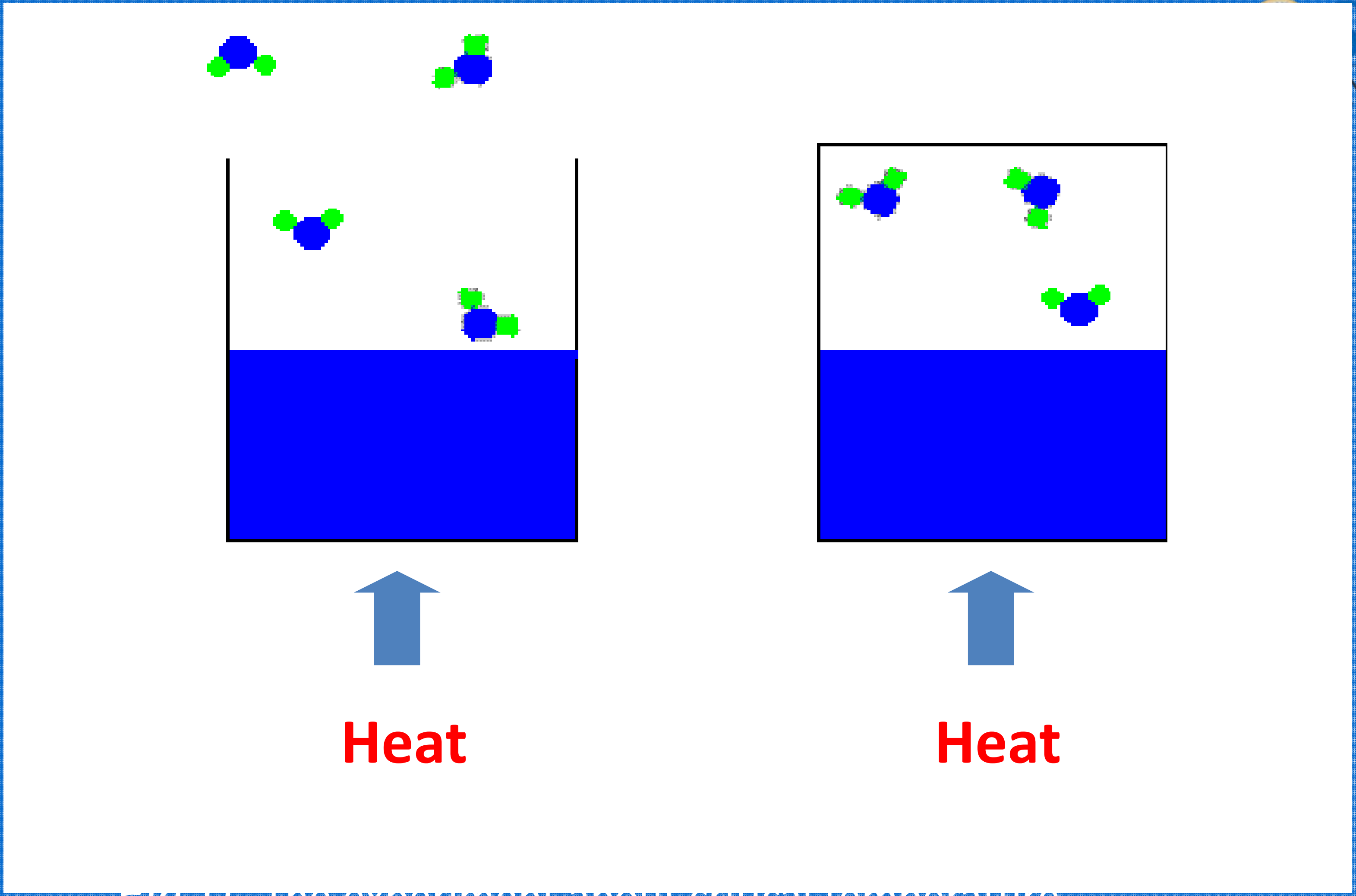


Fig 11. The experiment about critical temperature

- The temperature at which the surface disappear is the critical temperature

Melting

Freezing

The melting temperature (or freezing temperature) is the temperature at which, under the specified pressure, the liquid and solid phases of a substance coexist in equilibrium

Phase Diagrams

ISSUES TO ADDRESS...

- When we combine two elements...

  what equilibrium state do we get?

- In particular, if we specify...

  --a composition (e.g., wt% Cu - wt% Ni), and

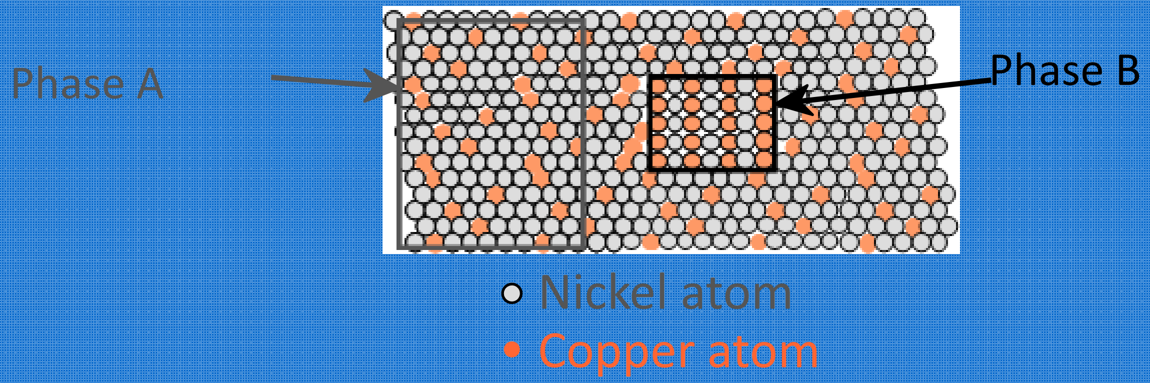
  --a temperature (T)

  then...

  How many phases do we get?

  What is the composition of each phase?

  How much of each phase do we get?



Phase Equilibria: Solubility Limit

Introduction

- Solutions – solid solutions, single phase
- Mixtures – more than one phase

- Solubility Limit:
  Max concentration for which only a single phase solution occurs.

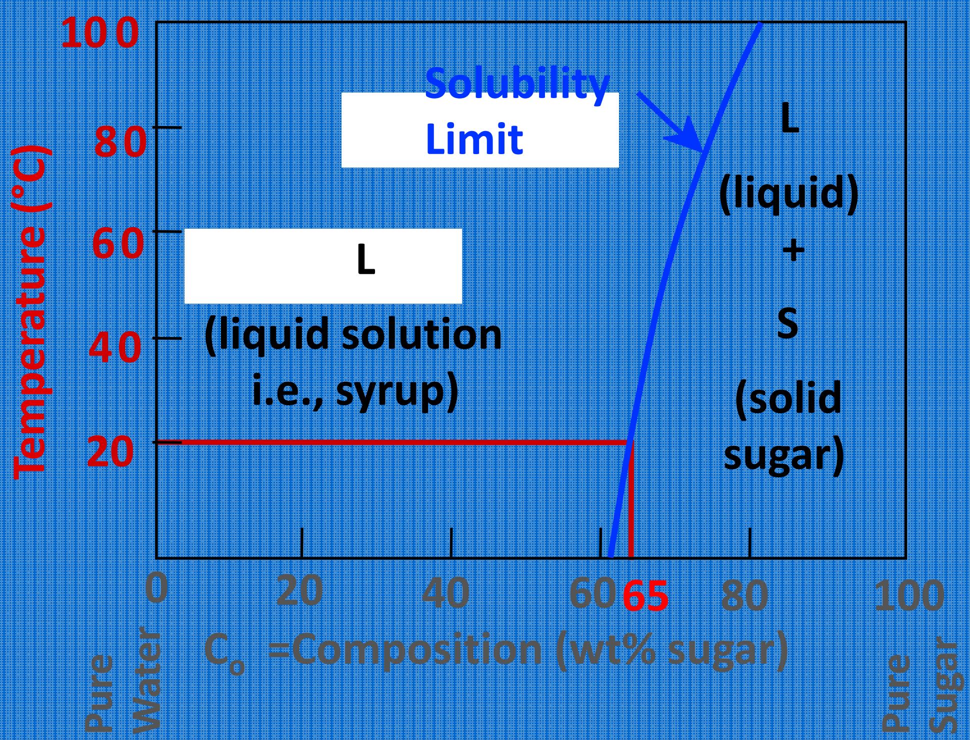
Question: What is the solubility limit at 20°C?

Answer: 65 wt% sugar.

If C_O < 65 wt% sugar: syrup

If C_O > 65 wt% sugar: syrup + sugar.

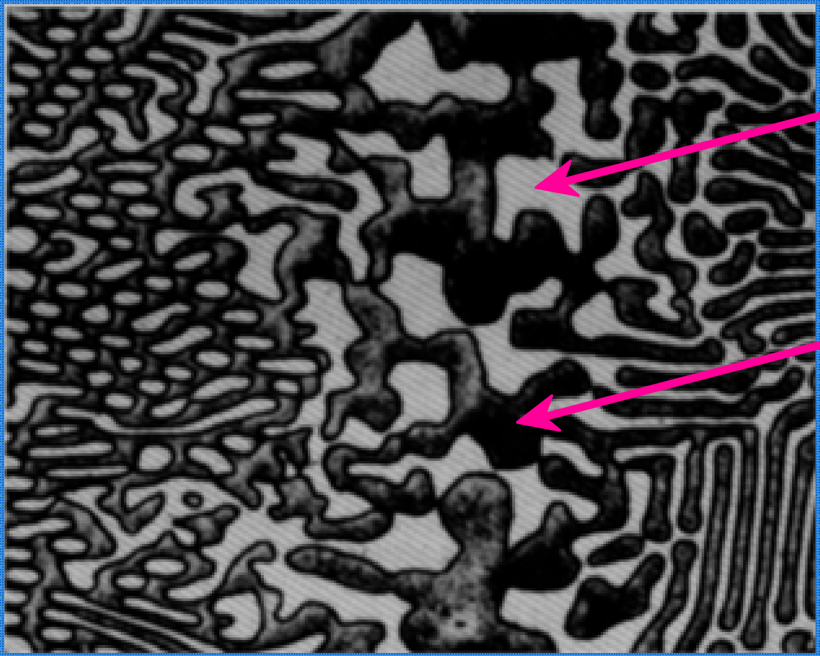
Sucrose/Water Phase Diagram



Components and Phases

- Components:
  The elements or compounds which are present in the mixture (e.g., Al and Cu)
- Phases:
  The physically and chemically distinct material regions that result (e.g., α and β).

Aluminum-Copper Alloy



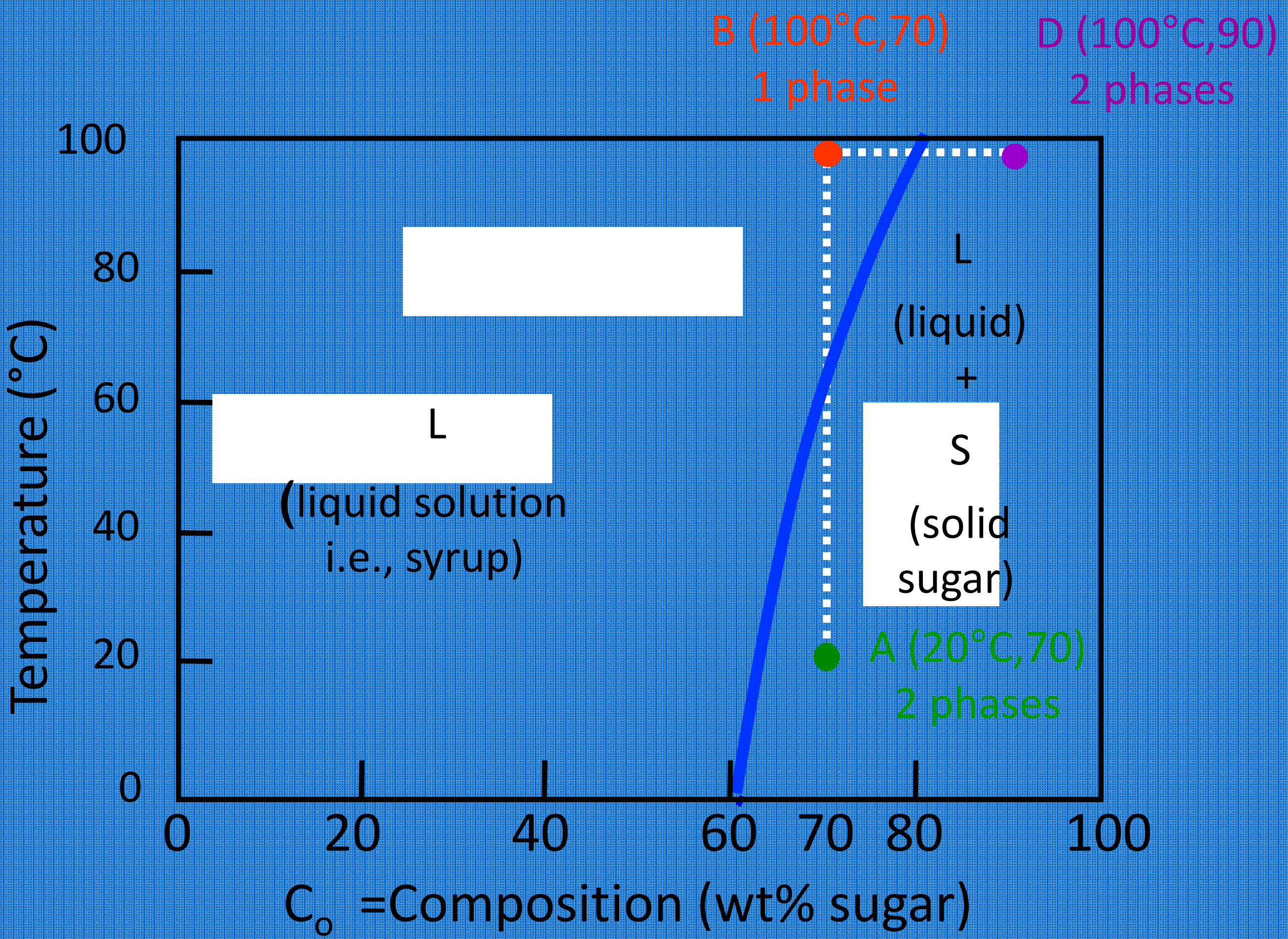
β (lighter phase)

α (darker phase)

Effect of *T* & Composition (C_o)

- Changing T can change # of phases: path A to B.
- Changing C_O can change # of phases: path B to D.

water-
sugar
system



Phase Equilibria

Simple solution system (e.g., Ni-Cu solution)

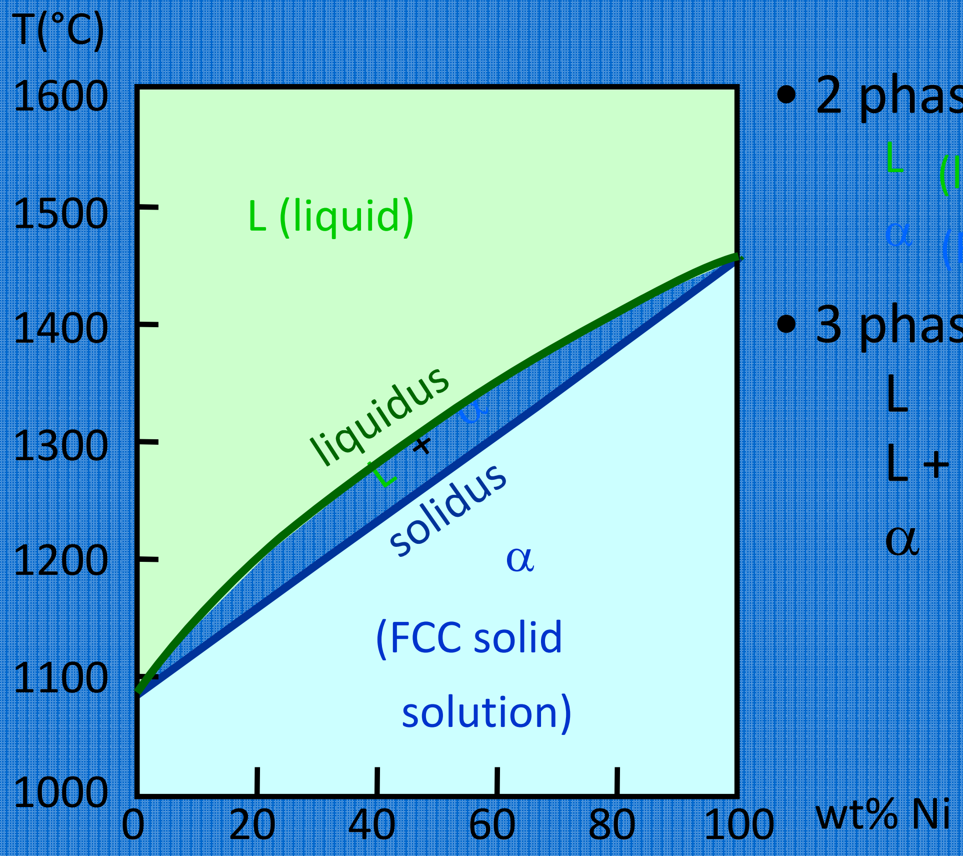
	Crystal Structure	electro negativity	*r* (nm)
Ni	FCC	1.9	0.1246
Cu	FCC	1.8	0.1278

- Both have the same crystal structure (FCC) and have similar electronegativities and atomic radii (W. Hume – Rothery rules) suggesting high mutual solubility.
- Ni and Cu are totally miscible in all proportions.

Phase Diagrams

- Indicate phases as function of T, C_O, and P.
- For this course:
  - -binary systems: just 2 components.
  - -independent variables: T and C_O (P = 1 atm is almost always used).

- Phase Diagram for Cu-Ni system



- 2 phases:
  - L (liquid)
  - α (FCC solid solution)
- 3 phase fields:
  - L
  - L + α
  - α

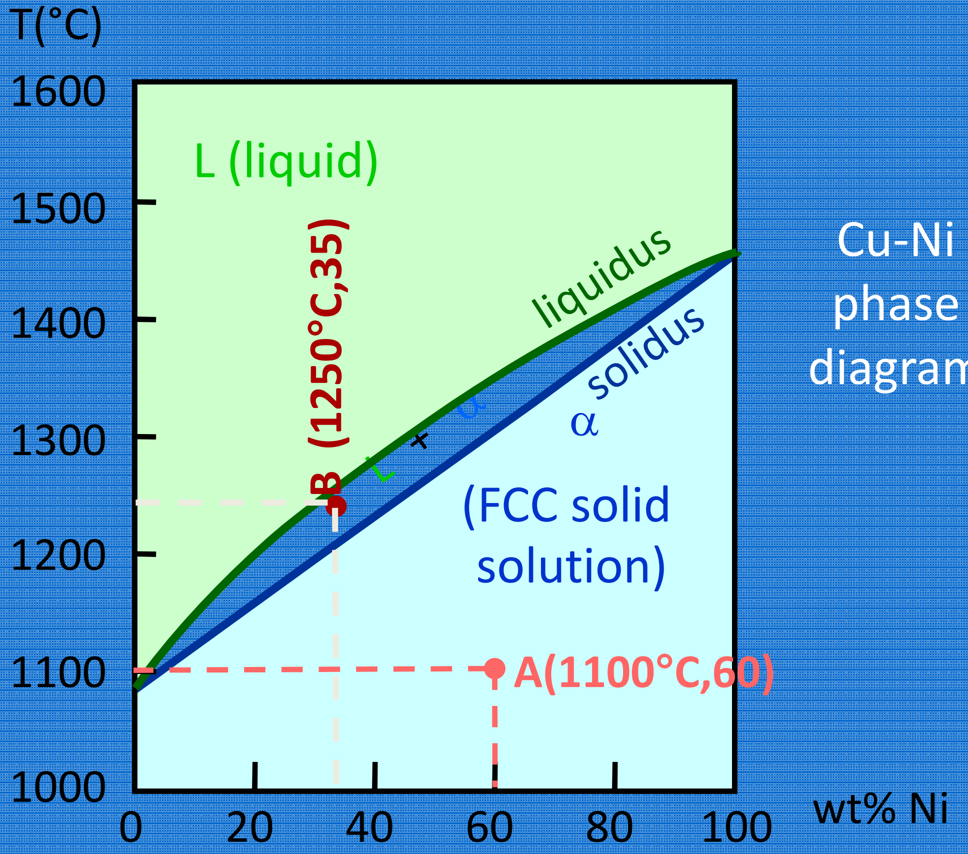
Phase Diagrams:
and types of phases

- Rule 1: If we know T and C_O, then we know:
  --the # and types of phases present.

- Examples:

  A(1100°C, 60):
  1 phase: α

  B (1250°C, 35):
  2 phases: L + α



Cu-Ni phase diagram

Phase Diagrams: composition of phases

- Rule 2: If we know T and C_o, then we know:
  --the composition of each phase.

- Examples:

C_o = 35 wt% Ni

At T_A = 1320°C:

Only Liquid (L)

$C_L = C_o$ (= 35 wt% Ni)

At T_D = 1190°C:

Only Solid (α)

$C_\alpha = C_o$ (= 35 wt% Ni)

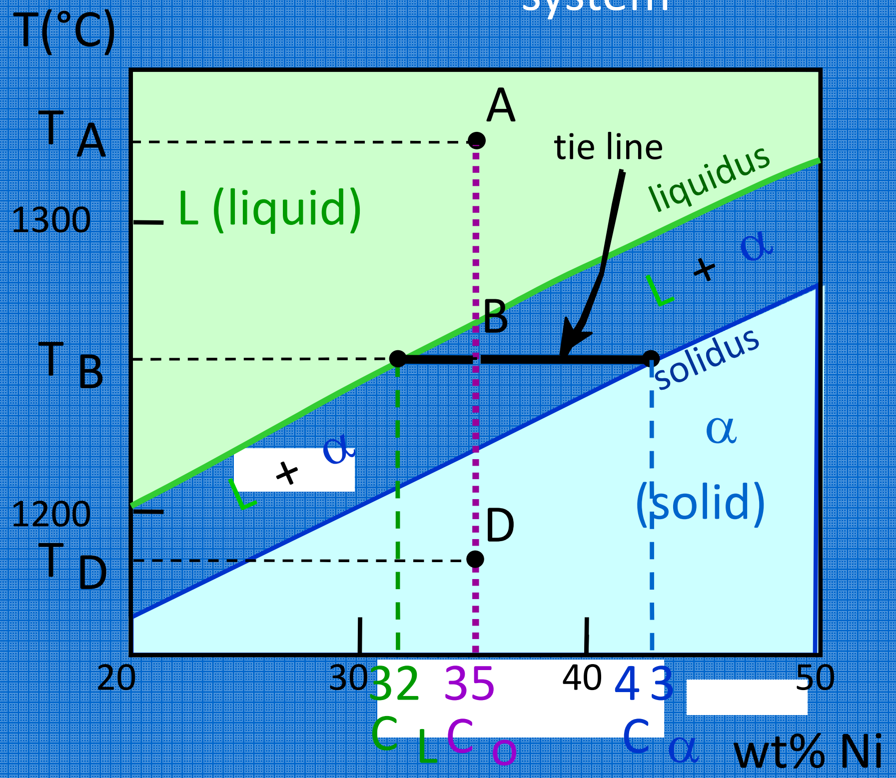
At T_B = 1250°C:

Both α and L

$C_L = C_{liquidus}$ (= 32 wt% Ni here)

$C_\alpha = C_{solidus}$ (= 43 wt% Ni here)

Cu-Ni system



Phase Diagrams: weight fractions of phases

- Rule 3: If we know T and C_O, then we know:
  --the amount of each phase (given in wt%).
- Examples:

C_O = 35 wt% Ni

At T_A: Only Liquid (L)

W_L = 100 wt%, $W_\alpha = 0$

At T_D: Only Solid (α)

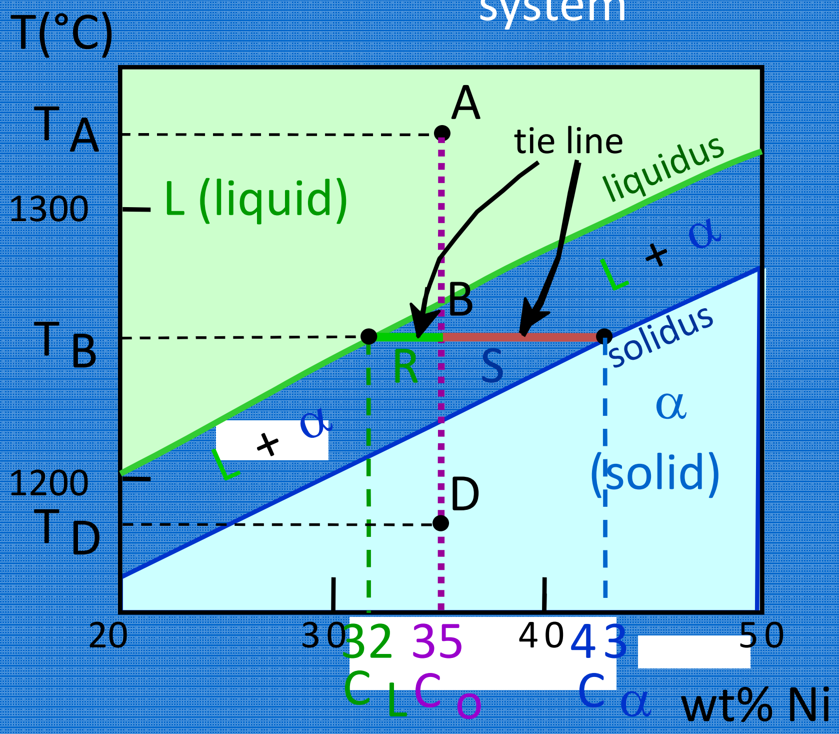
$W_L = 0$, W_α = 100 wt%

At T_B: Both α and L

$$W_L = \frac{S}{R+S} = \frac{43-35}{43-32} = 73\ wt\%$$

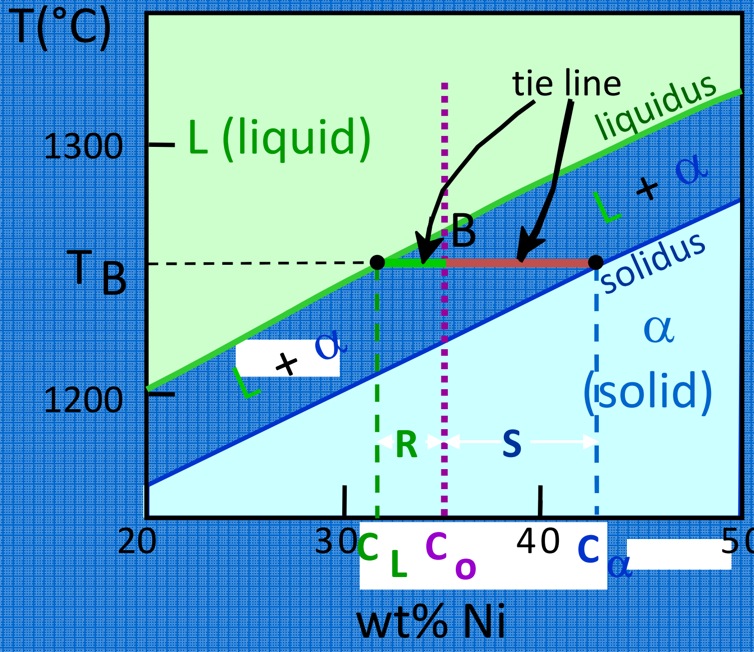
$$W_\alpha = \frac{R}{R+S} = 27\ wt\%$$

Cu-Ni system

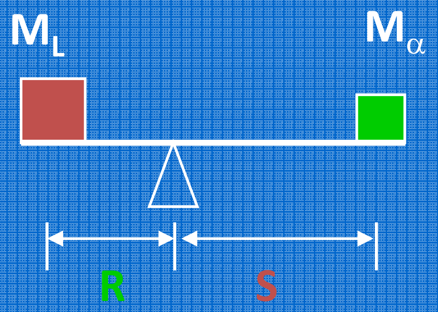


The Lever Rule

- Tie line – connects the phases in equilibrium with each other - essentially an isotherm



How much of each phase?
Think of it as a lever



$$M_\alpha \cdot S = M_L \cdot R$$

$$W_L = \frac{M_L}{M_L + M_\alpha} = \frac{S}{R+S} = \frac{C_\alpha - C_0}{C_\alpha - C_L}$$

$$W_\alpha = \frac{R}{R+S} = \frac{C_0 - C_L}{C_\alpha - C_L}$$

Fe-Fe_3C System