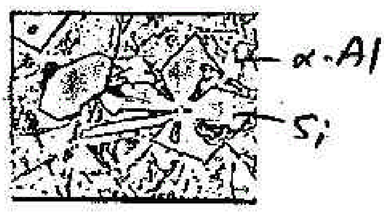
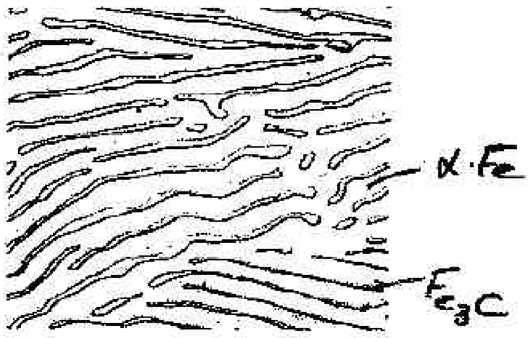
Phase Diagrams:

What is a phase?

- know of solid – liquid – gas (e.g. $H_2 0$ = ice, water, steam)
- materials - regions, which differ in structure and/or composition from another region are different phases.



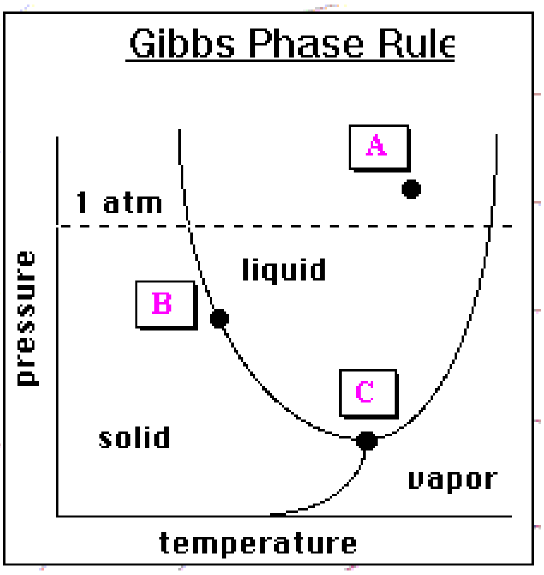


Phase must be:

- homogeneous in crystal structure and atomic arrangement.
- have same chemical and physical properties throughout
- have a definite interface and able to be mechanically separated from its surroundings.

(Can be a compound e.g. $H_2 0$, not restricted to elements)

Phase Diagram of a Pure Substance:



- graphical representation of the phases (of water) which exist under different conditions of temperature and pressure.

In pressure-temp diag.:
Triple point at C – solid, liquid and gas coexist.

Liquid and vapour coexist along vapourisation line.
Solid and liquid coexist along freezing line.
These are two-phase equilibrium lines

Gibbs Phase Rule:

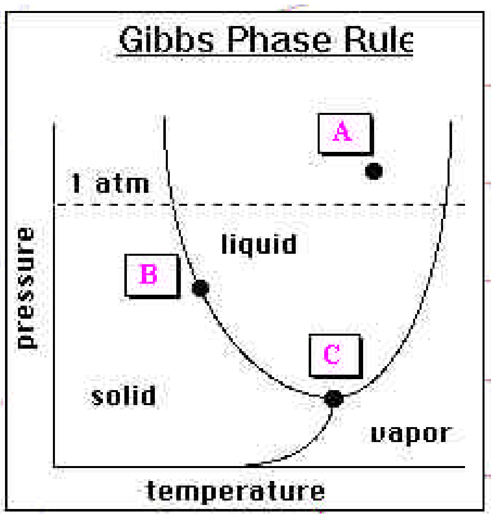
Used to determine the degrees of freedom, or number of variables that can be changed independently while still remaining in the same phase.

$$F = C - P + 2$$

F - degrees of freedom,
C - number of components, usually elements or compounds.
P - number of phases present,
And **2** implies that both variables (pressure and temperature) are able to change.

Ex.

Point A lies in a single-phase region. Either variable, temperature or pressure may be changed independently while still remaining in the liquid phase. Therefore there are two degrees of freedom.

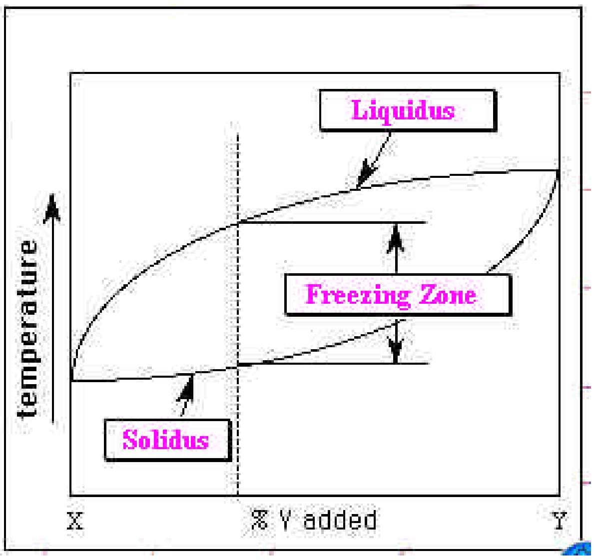


$$F = C - P + 2$$
$$F = 1 - 1 + 2$$
$$F = 2$$

Point B lies on a two-phase boundary. If one variable is changed, then the other variable is forced to change in order to stay on this boundary line. Only one variable is free to move independently at a time. Therefore there is only one degree of freedom. (F=1)

Point C lies on the triple point. At this point all three phases coexist at the same time. In order to remain at this three-phase point no variable may be changed. Therefore there are zero degrees of freedom. (F=0)

Most phase diagrams used in materials sci. are temperature composition diagrams – pressure is const (1 atm.) Gives condensed phase rule
$P+F=C+1$



Phase Diagrams:

"Like a map."
If temp and amount of added alloy are known then can find that phases are present.

Note: like a map, location tells you the present state of things - not how you got there.

The phase diagram is also known as a "state diagram" or equilibrium diagram

Liquidus temperature:
Above this line the sample is entirely liquid. Upon reaching this line during cooling, the first solids begin to form.

Freezing zone.:
- It is the temperature difference between the liquidus and solidus lines.
- two phases exist at all times.
- the amounts of the two phases (the pro-portion of solid to liquid)

Solidus temperature.
Only areas completely below this line are completely solid. When the solid is heated, the first bit of liquid will form above this line.

Solubility?

Few materials consist single element or component. Most are mixtures or combinations - intentional to produce particular properties, or possibly impurities.

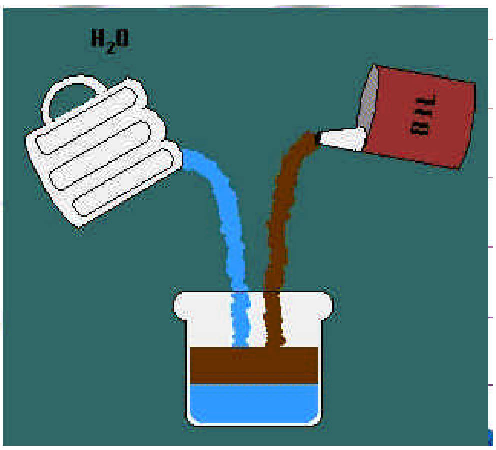
Look at solutions and solubility.

Some materials are rather reluctant to form solutions (e.g., water and oil), while other materials easily mix in any amount (e.g., water and alcohol).

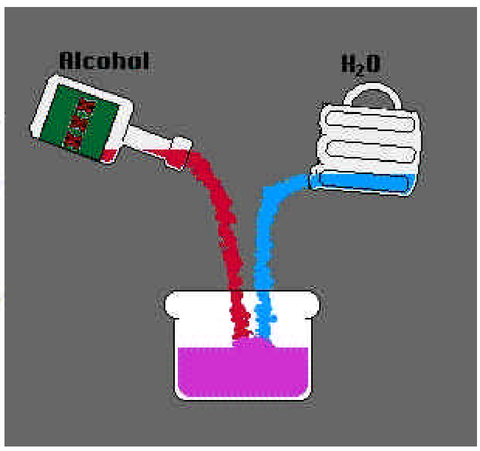
Solutions can form in solids & liquids. The amount of one substance that can be dissolved into another is its solubility.

Three different categories:
limited solubility, unlimited solubility, and no solubility.

Limited solubility - sugar/water



No solubility - oil/water



Unlimited solubility – alcohol/wate

Can try these at home!

Limited Solubility: only a certain amount of one substance may completely dissolve into the other substance. If this level of solubility is surpassed then one of the original components will remain – now **two phases** exist.
Many materials behave this way. Cu and Zn are two metals that display limited solubility.

No Solubility: 2 substances are insoluble, almost none of either substance will dissolve in the other. Most materials will dissolve at least a tiny amount of another component, but when the max amount - often described as insoluble. Pb and Cu are considered insoluble.

Unlimited Solubility: 2 substances must be able to dissolve completely into any amount of the other substance. After the solution is thoroughly mixed only **one phase** is produced. Cu and Ni are good examples of metals that display unlimited solubility.

Hume-Rothery Rules

The Hume-Rothery rules are conditions that must be satisfied in order for unlimited solubility to take place. These conditions are:

1. Size: Atoms may only have a 15% difference radius, otherwise the strain on the lattice will be too great.

2. Crystal Structure: Each pure component must form the same crystal structure.

3. Electronegativity: Each atom must have approximately the same electronegativity. Great differences in electronegativity will encourage the formation of ionic compounds, not solutions.

4. Valence: Each atom must have the same valence. (prevention of forming compounds – mostly univalent)

Note: These conditions not only apply to elements but also compounds, including ceramic compounds such as MgO and NiO.