# Kap. 4
# Phase diagrams

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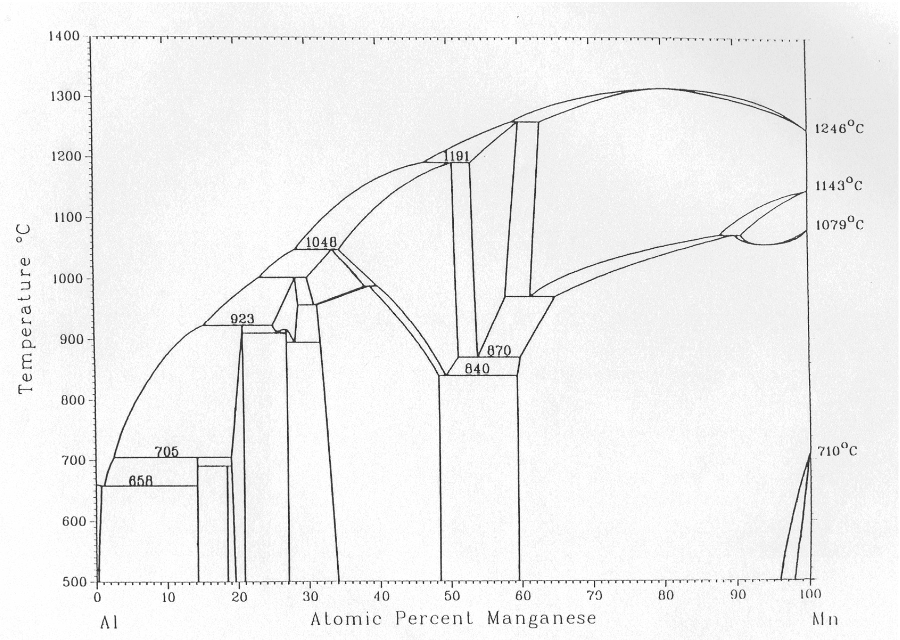
## Phasediagrams



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## Gibbs phase rule

**P + F = C + 2**

The **Degrees of Freedom** [F] or **Variance** [v] is the number of independent intensive variables (i.e. those that are independent of the quantity of material present) that need to be specified in value to fully determine the state of the system. Typical such variables might be temperature, pressure, or concentration.

A **Phase** [P] is a component part of the system that is immiscible with the other parts (e.g. solid, liquid, or gas); a phase may of course contain several chemical constituents, which may or may not be shared with other phases. The number of phases is represented in the relation by **P**.

The **Chemical Constituents** [C] are simply the distinct compounds (or elements) involved in the equations of the system. (If some of the system constituents remain in equilibrium with each other whatever the state of the system, they should be counted as a single constituent.) The number of these is represented as **C**.

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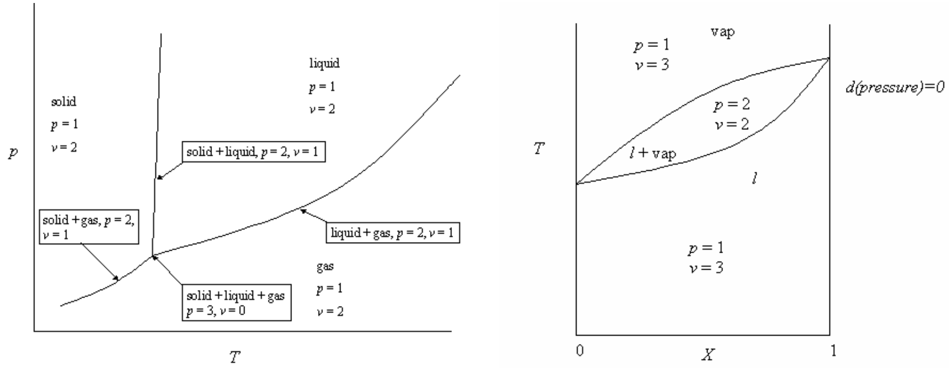
## Gibbs phase rule



# Thermodynamic stability

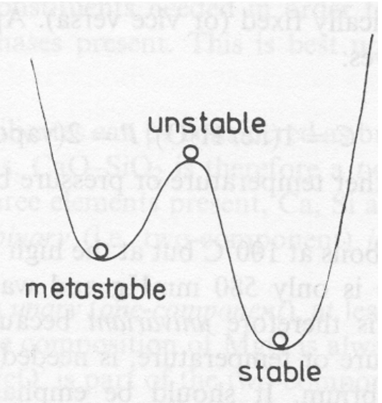


**Fig. 6.2** Schematic diagram showing stable, unstable and metastable conditions

**Phase diagrams only show the thermodynamically stable plhases.**
**If they show metastable compounds they are called existence or dominance diagrams.**

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# One component diagrams

**P + F = 1 + 2**

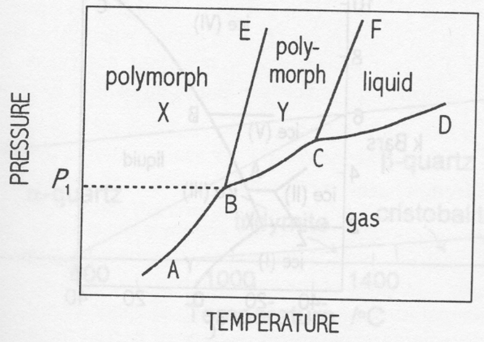

Fig. 6.3 Schematic pressure versus temperature phase diagram of a one-component system

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# One component diagrams

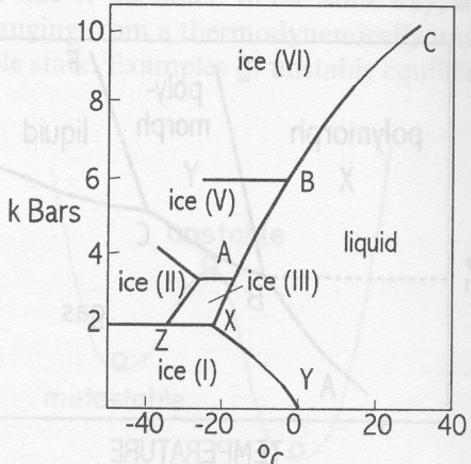

**Fig. 6.4** The system $H_2O$

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# One component diagrams

**P + F = 1 + 2**

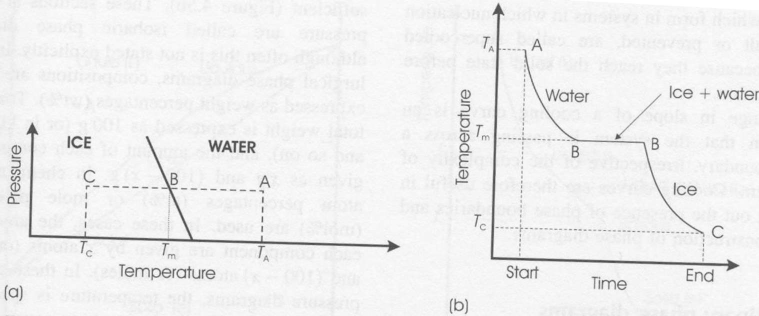

**Figure 4.3** (a) A small part of the water phase diagram and (b) the cooling curve generated as a uniform sample of water cools from temperature A (liquid) to temperature C (solid; ice)

not to scale

## One component diagrams

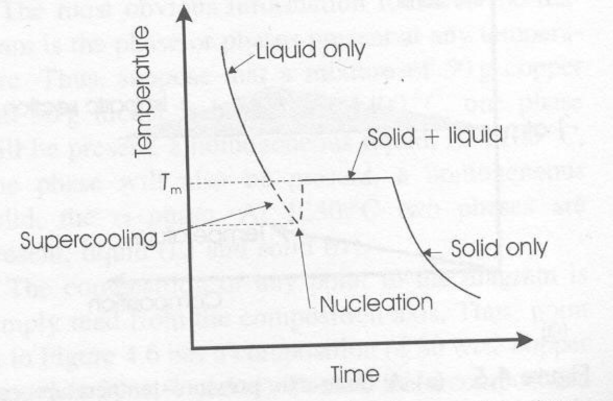

**Figure 4.4** A cooling curve showing supercooling

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## One component diagrams

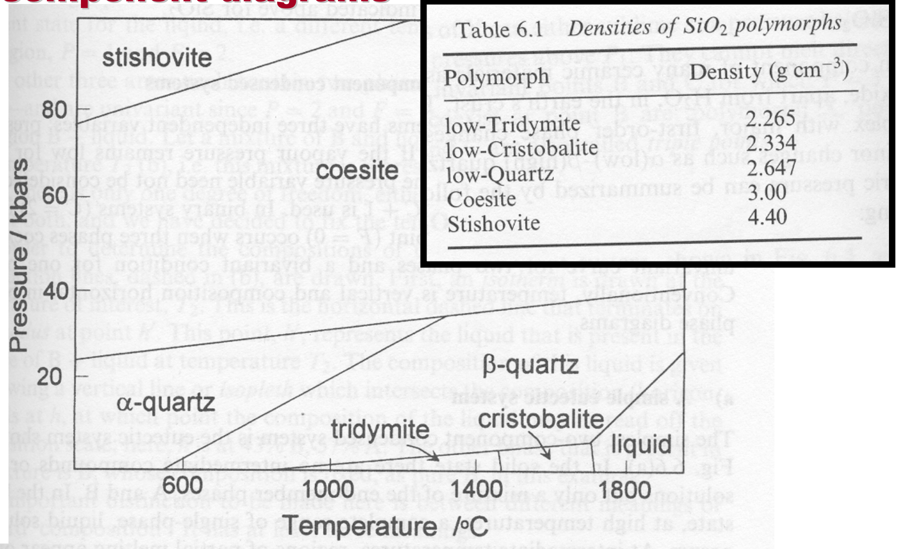

Fig. 6.5 The system $SiO_2$. (Adapted from Griffin, *Silicate Crystal Chemistry*, Oxford, 1992)

Table 6.1 *Densities of $SiO_2$ polymorphs*

| Polymorph | Density (g cm$^{-3}$) |
|---|---|
| low-Tridymite | 2.265 |
| low-Cristobalite | 2.334 |
| low-Quartz | 2.647 |
| Coesite | 3.00 |
| Stishovite | 4.40 |

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## One component diagrams

**P + F = 1 + 2**

573 °C 870 °C 1470 °C 1710 °C

α-Quarts → β-Quarts → β-Tridymite → β-Cristobalite → liquid

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## Simple complete solid solution

**P + F = 2 + 2**

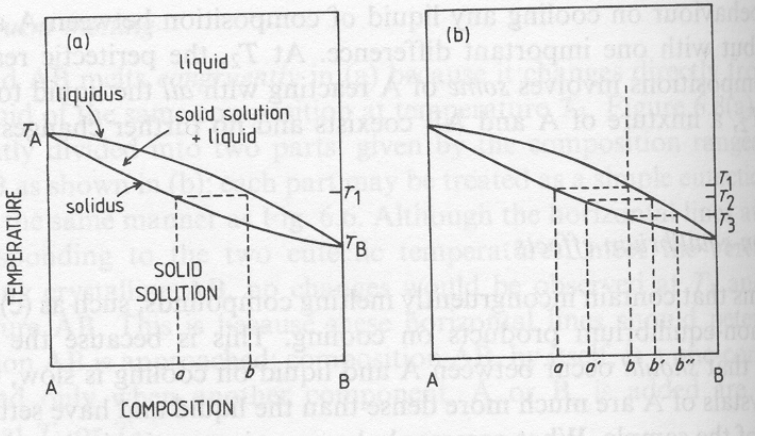

**Fig. 6.10** Binary system with a complete range of solid solutions

## Simple complete solid solution

**P + F = 2 + 2**

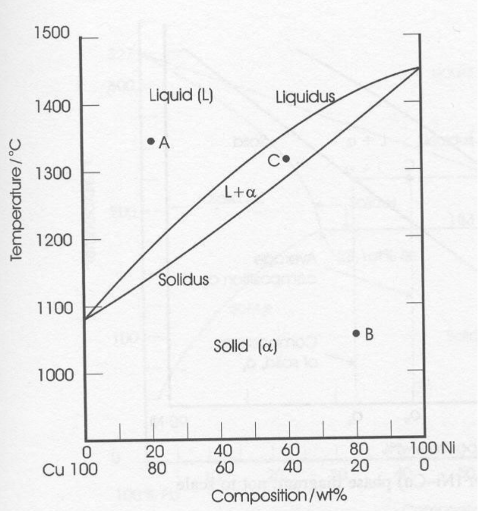

**Figure 4.6** The nickel–copper (Ni–Cu) phase diagram at atmospheric pressure

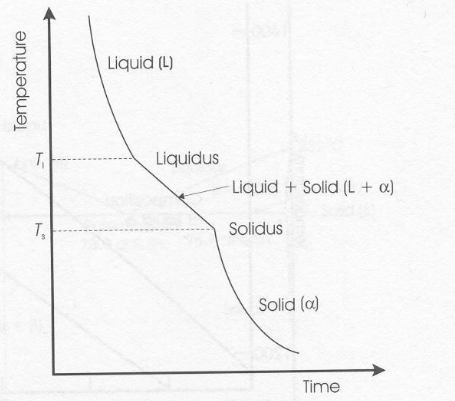

**Figure 4.7** A cooling curve for a sample passing through a two-phase liquid + solid region

## Simple complete solid solution

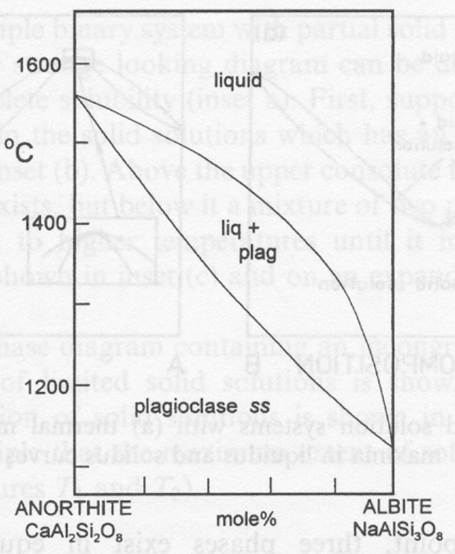

**Fig. 6.11** The plagioclase feldspar system, anorthite–albite

## Simple complete solid solution

**P + F = 2 + 2**

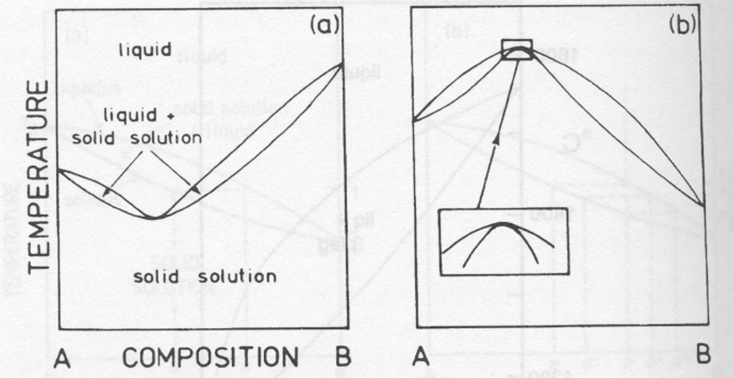

**Fig. 6.12** Binary solid solution systems with (a) thermal minima and (b) thermal maxima in liquidus and solidus curves

## Simple eutectic

**L -> A + B**

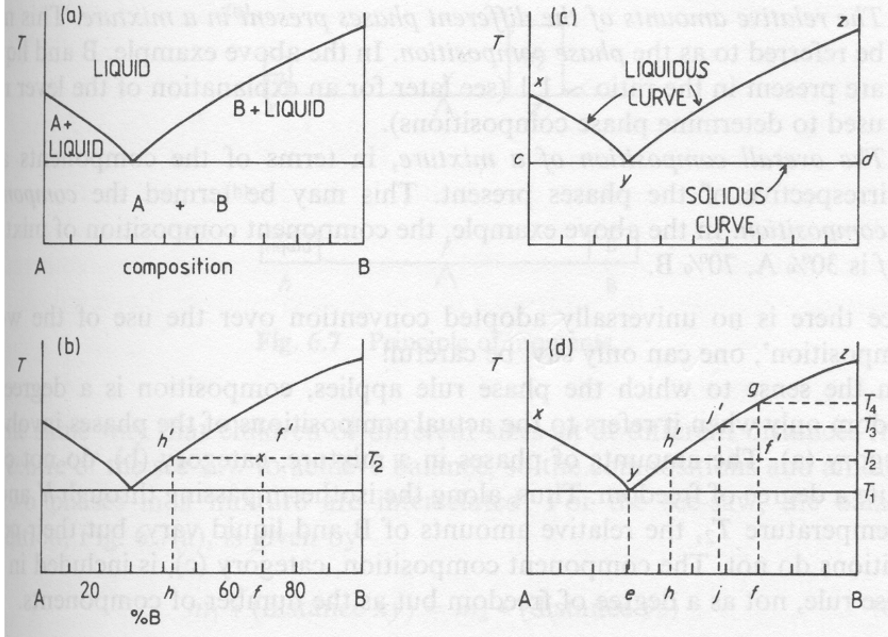

**Fig. 6.6** Simple eutectic binary system

# Simple eutectic

## P + F = 2 + 2

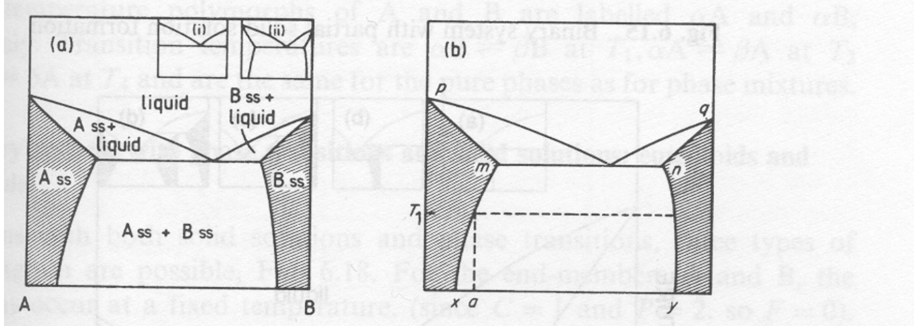

Fig. 6.13 Simple eutectic system showing partial solid solubility of the end members

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# Simple eutectic

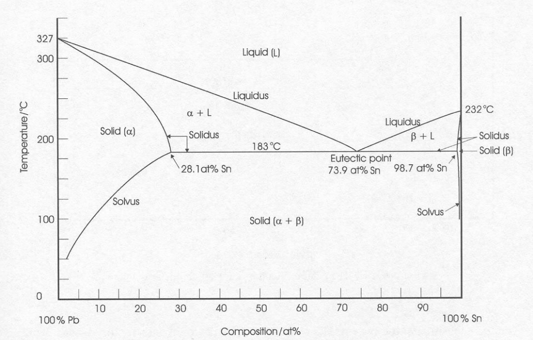

**Figure 4.9** The lead–tin (Pb–Sn) phase diagram at atmospheric pressure

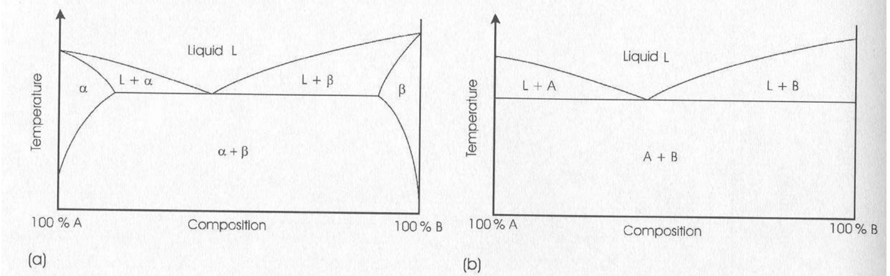

**Figure 4.13** (a) A typical binary metallurgical phase diagram; (b) a typical ceramic (nonmetallic) phase diagram

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# Simple eutectic

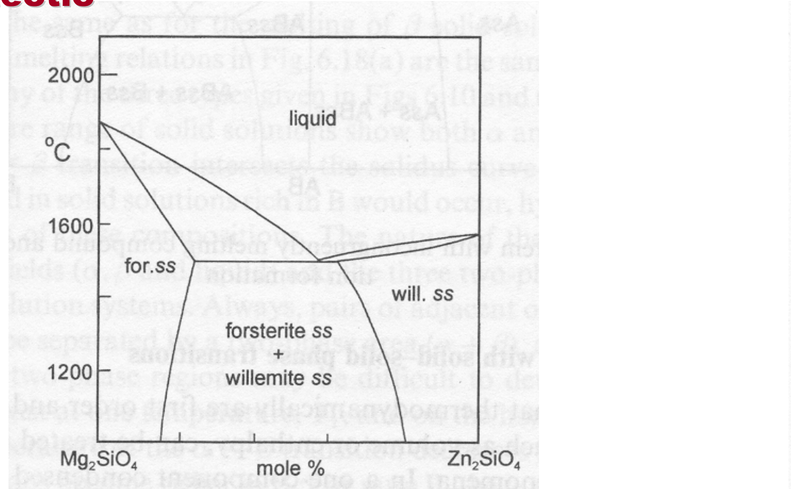

Fig. 6.14 The system $Mg_2SiO_4$–$Zn_2SiO_4$. (E.R. Segnit and A.E. Holland, *J. Amer. Ceram. Soc.*, **48**, 412, 1965)

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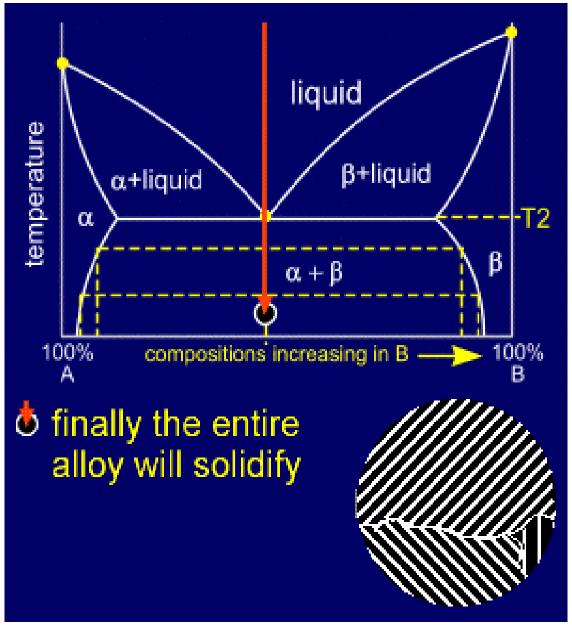
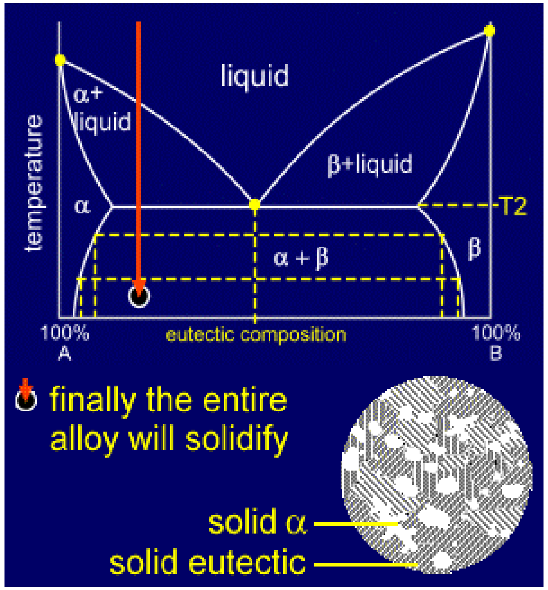
# Simple eutectic



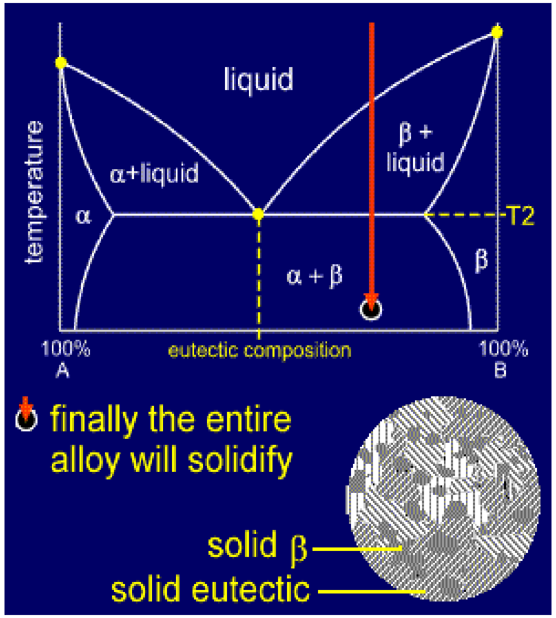
finally the entire alloy will solidify

## Simple eutectic



finally the entire alloy will solidify

## Simple eutectic



finally the entire alloy will solidify

## Complex eutectic

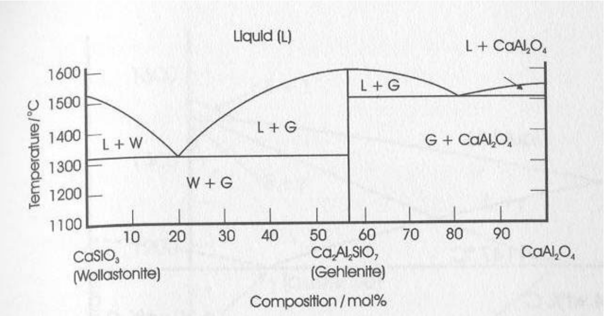


**Figure 4.14** The wollastonite–calcium aluminate ($CaSiO_3$–$CaAl_2O_4$) phase diagram showing the intermediate phase gehlenite, $Ca_2Al_2SiO_7$

## Complex eutectic