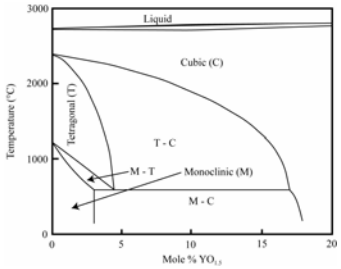
Class 5: Introduction to Phase Diagrams



Cut of ZrO2-YO Phase Diagram: H. G. Scott, Phase relations in the zirconia-yttria system, Journal of Materials Science, 10 [9] 1527-1535 (1975)

PRIME Modules
Project-based Resources for Introduction to Materials Engineering

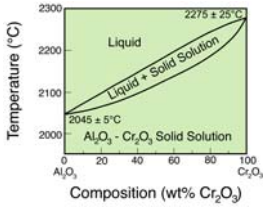
A phase diagram is a plot of the stable phase(s) present as a function of T and composition

Phase diagrams document the stable (predicted phase) as a function of temperature, composition, and/or pressure. The most common phase diagrams are at 1atm pressure and plot T vs composition.

We will talk about 3 types of phase diagrams

- isomorphous
- eutectic
- eutectoid

In SOFC, phase diagrams are utilized in the selection of new materials to determine if the material will be stable at room temperature and at the temperatures the SOFC operate at



Adapted from Callister

A phase is a homogeneous portion of a system that has uniform physical and chemical characteristics.

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Examples:

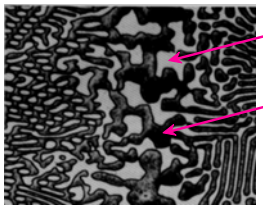
Pure Iron
Steel - Solid Solution of Iron and Carbon
Syrup - Liquid Solution of Sugar and Water
Ice

Is ice-water a single phase?

What is the difference between component and phase?

- Components:
  The elements or compounds which are mixed initially (e.g., Al and Cu, or Al_2O_3 and Cr_2O_3)
- Phases:
  The physically and chemically distinct material regions that result (e.g., α and β).

Aluminum-Copper Alloy



Adapted from Fig. 9.0, *Callister 3e.*

Adapted from Callister

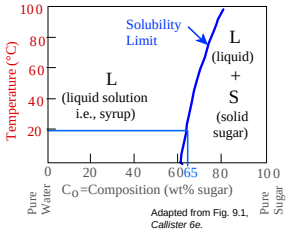
The solubility limit is the maximum concentration for which only 1 phase exists

What is the solubility limit at 20C?

Answer: 65wt% sugar.
If C_o < 65wt% sugar: sugar
If C_o > 65wt% sugar: syrup + sugar.

How does the solubility limit change with temperature?

Solubility limit increases with T:
e.g., if T = 100C,
solubility limit = 80wt% sugar.



Adapted from Fig. 9.1, *Callister 6e.*

Phase Diagram: Water-Sugar System

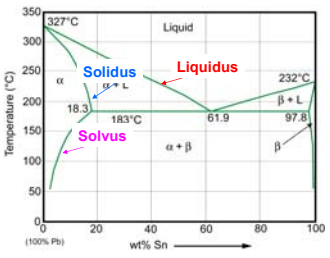
Adapted from Callister

The lines on the phase diagrams mark out solubility limits

Solidus line marks out the line between a solid and solid + liquid regions

Liquidus line marks out the line between a liquid and solid + liquid regions

Solvus marks out the region where a second phase precipitates out from a solid

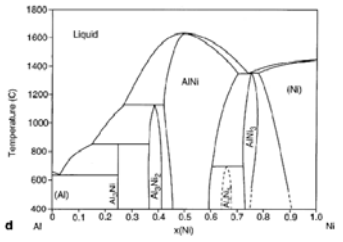


Phases of reach region are determined by the phases of the regions to the left and right

In standard phase diagrams, two phase regions are often not labeled.

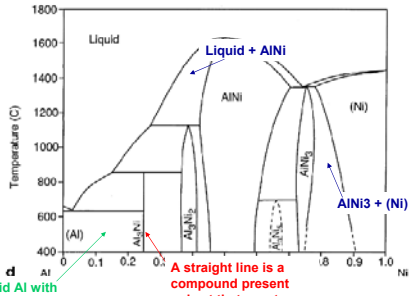
The phases present in that region are the phases from the single phase regions to the left and right.

In other words, that unlabeled 2 phase region is a transition (contains both) of the 1 phase regions



http://www.tms.org/pubs/journals/JOM/9712/Kattner-9712.fig.2d.gif

Al-Ni Example



(Al) is solid Al with some Ni dissolved in it

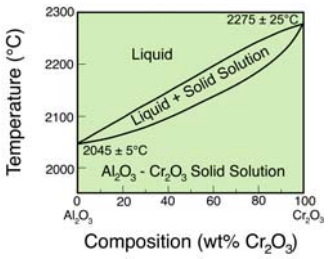
A straight line is a compound present only at that exact composition

http://www.tms.org/pubs/journals/JOM/9712/Kattner-9712.fig.2d.gif

An isomorphous phase diagram has 1 solid phase

In an isomorphous phase diagram, there is complete solid solubility between component A and B.

This means that as you go from pure A to pure B, you have only 1 phase.

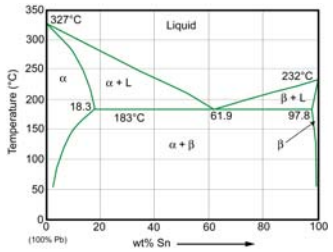


Adapted from Callister

A eutectic phase diagram contains a point where liquid transforms directly to 2 solids

A eutectic phase diagram has an invariant point.

At this point, liquid transforms directly into 2 solids
L→ α + β



Adapted from Callister
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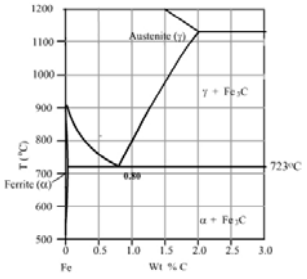
A eutectoid phase diagram contains a point where a solid transforms directly to 2 other solids

A eutectoid phase diagram has an invariant point.

At this point, 1 solid transforms directly into 2 other solids
δ → γ + ε



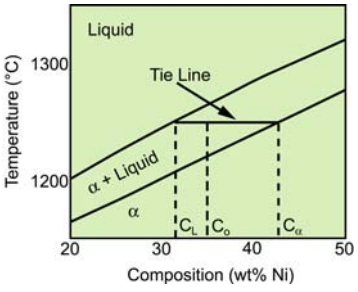
http://www-g.eng.cam.ac.uk/mmg/teaching/typd/addenda/eutectoidreaction1.html

A tie line is used to determine the composition of the phases in a 2 phase region

Draw a line horizontal to the x axis at the desired temperatue.

This is a tie line.

The intercept of the line with the solidus, liquidus, or soluvs lines gives the composition of the two phases.



Adapted from Callister

In summary, phase diagrams predict the equilibrium phases and compositions

Phase diagrams plot the equilibrium phases as a function of temperature, composition, (and and sometimes pressure).

Three main types of phase diagrams are isomorphous, eutectic, and eutectoid.

The solidus, liquidus, and solvus lines mark out the two phase regions.

Two phase regions can be labeled by the signle phase regions to the left and right.

Tie lines are used to determine the composition in 2 phase regions.