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ENR116 Engineering Materials

Module 3 Metals

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• My name is Drew Evans, and welcome to Module 3 – Metals

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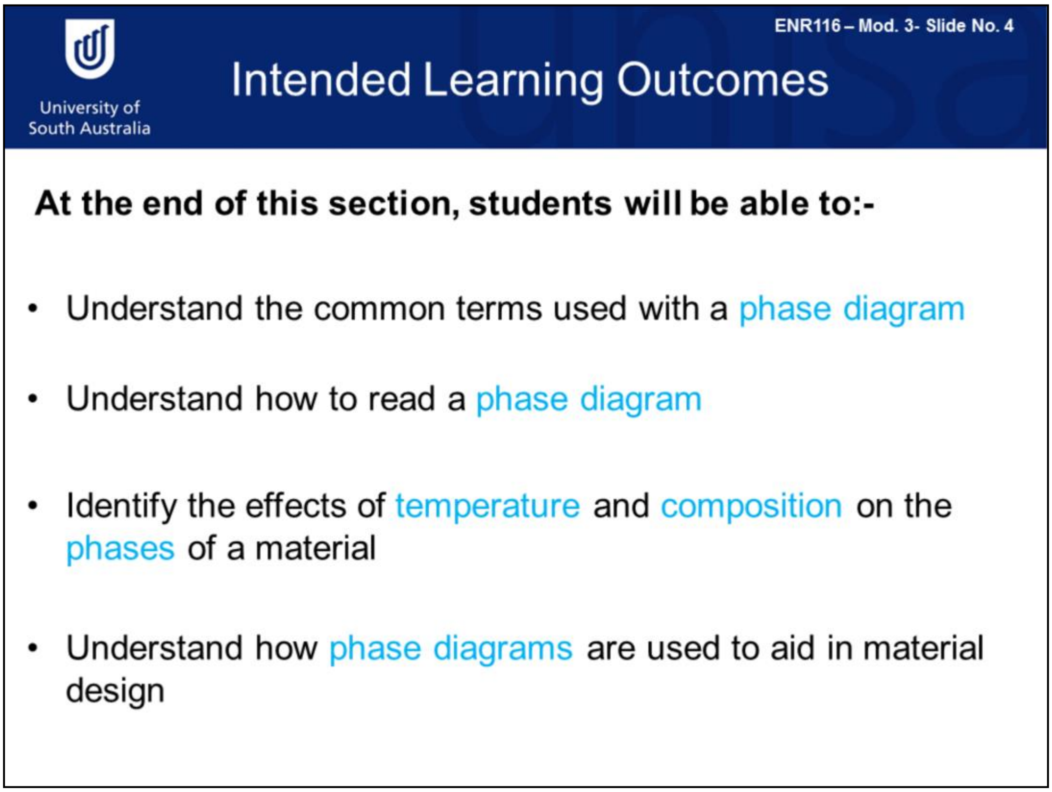
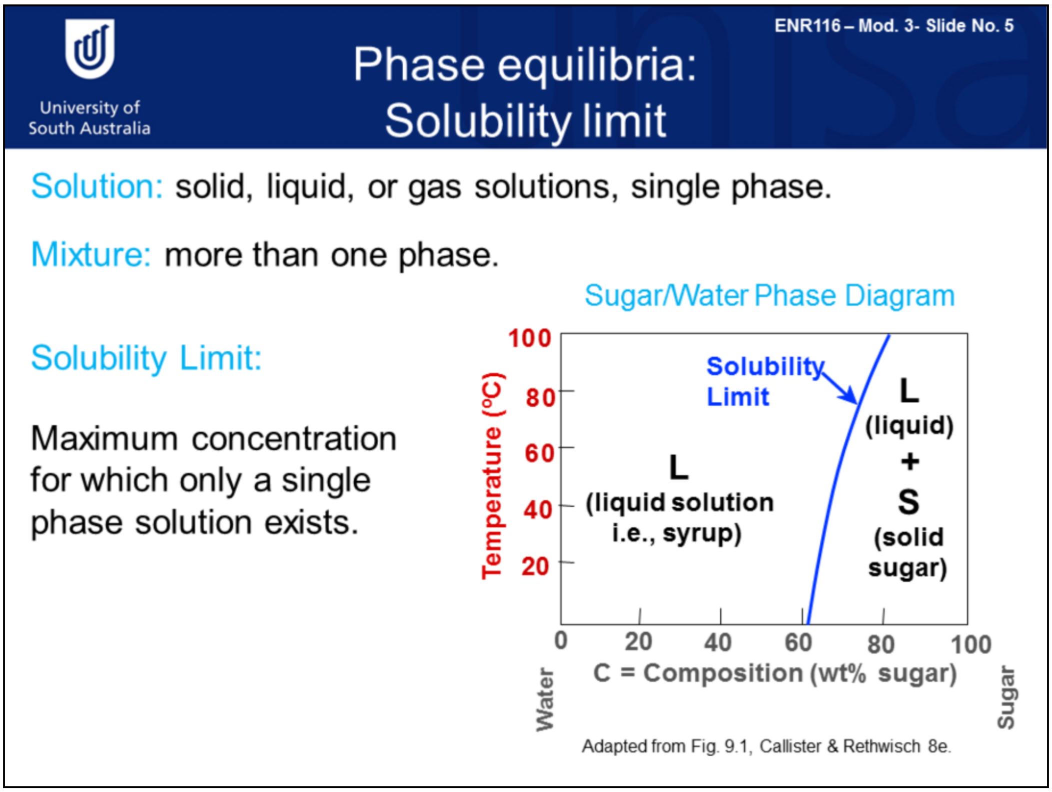
• This presentation will cover an Introduction to Phase Diagrams



By the end of this presentation, you should be able to,

- Understand the common terms that are used with a Phase Diagram
- Understand how to read a Phase Diagram
- Identify the effects that temperature has on the phases observed for a given composition of a material
- Understand how phase diagrams are used to aid in material design



When two elements are mixed together they can form either a,

Solution: a single phase of solid, liquid or gas

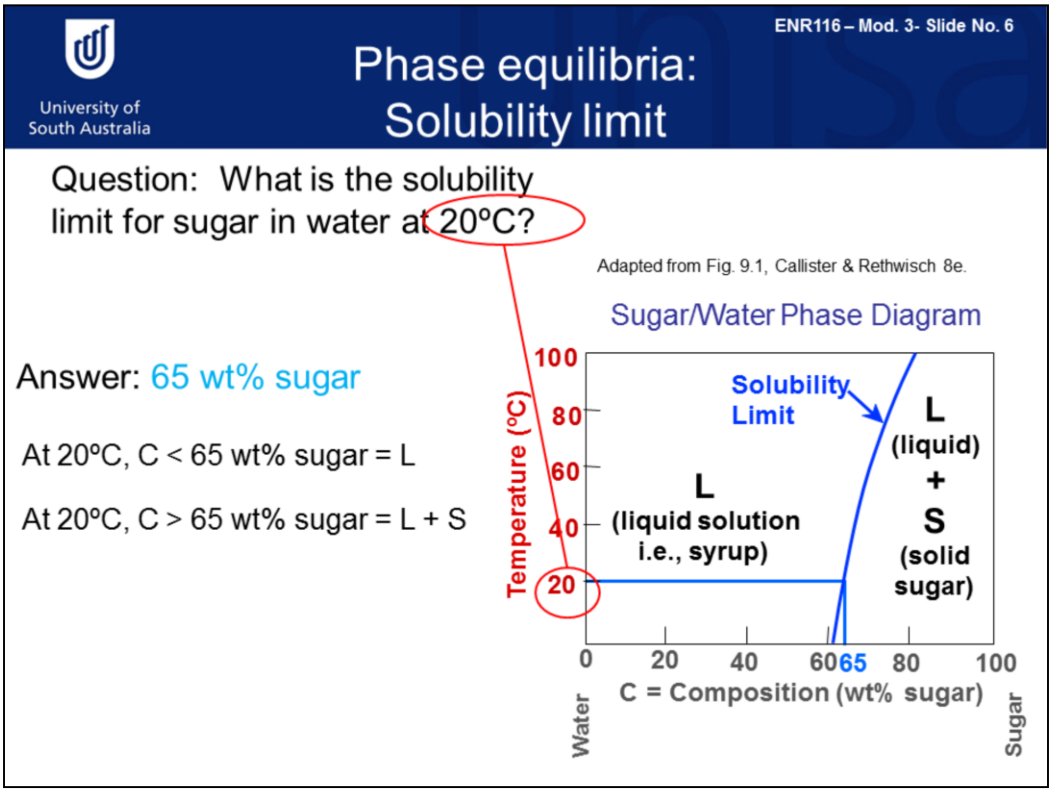
Mixture: two or more single phases present at the same time

The phases present at a given material composition depends on the solubility of one element in another

The transition from a single phase to a mixture of phases is defined as the solubility limit

For example, lets look at the Sugar-Water system

- At low concentrations of sugar in water, a single phase is present
- At high concentrations of sugar in water, a mixture of phases are present
- The transition between these represents the solubility limit, which is a function of the Composition and Temperature
- A phase diagram is used to capture this information



How do we use a Phase Diagram?

As an example, let's determine the solubility limit (Composition) of sugar in water at 20°C

To do this, draw a horizontal line across the Phase Diagram at 20°C until it intersects with the Solubility Limit line

Then from this intersection, draw a vertical line which crosses the x-axis

The x-intercept gives the Composition of sugar in water at the solubility limit when at 20°C

In this case, the Composition at 20°C at the solubility limit is 65 wt% of sugar in water

At Compositions below 65 wt%, a single phase is present, in this case a liquid solution

At Compositions above 65 wt%, a mixture of phases are present, in this case a liquid solution plus solid sugar

Importantly, the concept of solubility equally applies in the case of mixing two solids, as it does to the example here involving a solid and a liquid

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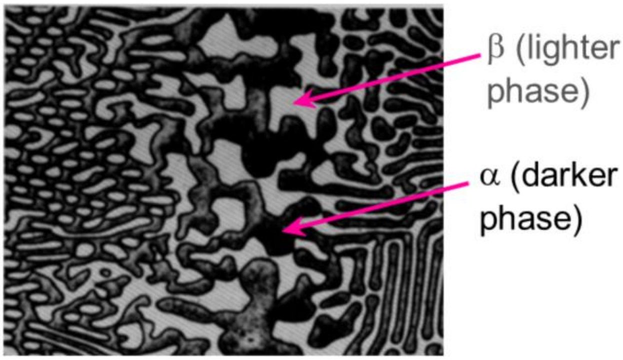
Components and phases

Components: The elements or compounds which are present in the alloy (e.g., Al and Cu).

Phases: The physically and chemically distinct material regions that form (e.g., α and β).

Aluminum-Copper Alloy



Adapted from chapter-opening photograph, Chapter 9, Callister, Materials Science & Engineering: An Introduction, 3e.

When dealing with Phase Diagrams, it is important to understand the terminology that is commonly used

The term Components is used to refer to the elements or compounds that are being mixed together

For example, Al and Cu in a binary alloy, or sugar and water in the case of the example from the previous slide

The term Phase or Phases is used to describe the distinct materials that form at a given temperature and composition

For example, in the micrograph of an AlCu alloy, two distinct phases can be observed, labeled as alpha and beta

Each phase has certain physical and chemical characteristics, which may be exploited for designing materials for a given application

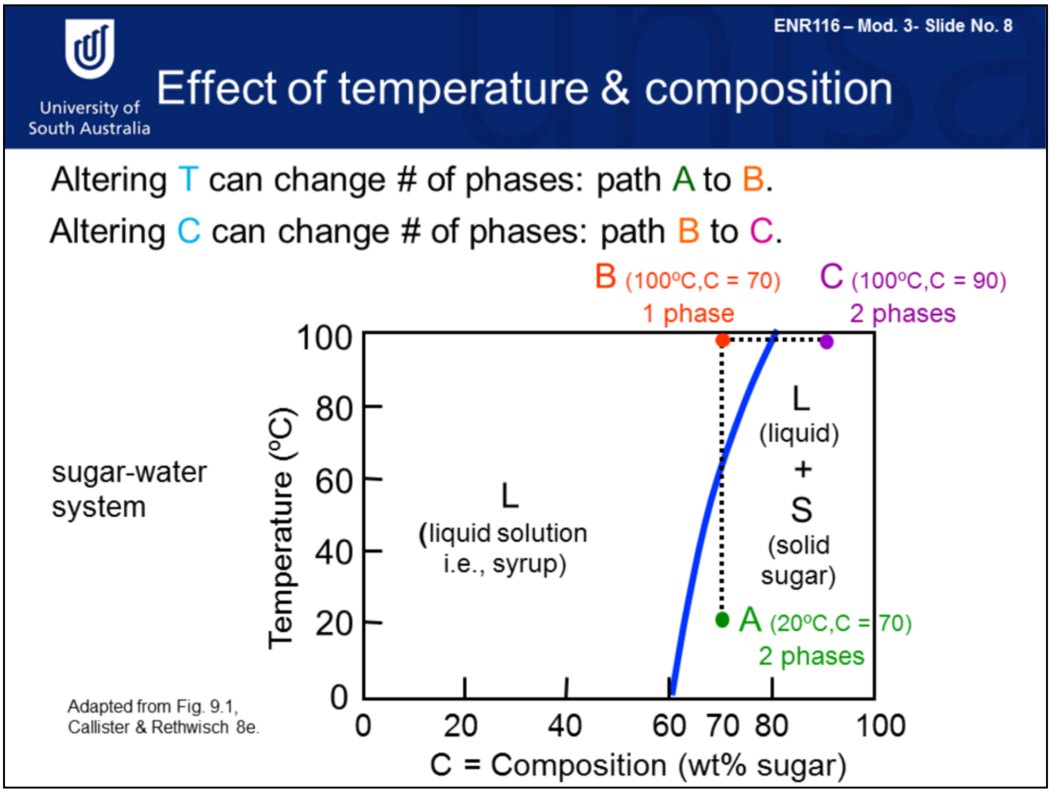
In essence, the Phase Diagram is a useful tool to allow an engineer to,

select the right Components

mix them at the right Composition and process them at the right Temperature

in order to generate a given Phase or mixture of Phases

so as to create a material with the right physical and chemical properties for their desired application



To use a Phase Diagram, it is important to appreciate how to navigate from one Phase to another by controlling the Composition and/or Temperature

At a fixed Composition, the Temperature can be varied to change the number and type of Phases present

For example, starting at point A on the sugar-water Phase Diagram (20°C and 70 wt% sugar) there are two phases present, liquid and solid sugar

Increasing the Temperature to 100°C, without changing the Composition, results in one phase being observed (the liquid phase)

This is because we have increased the solubility of the sugar in the water by raising the temperature, so the solid sugar now dissolves in the water

Now, if the Temperature is held at 100°C and Composition is changed by adding more sugar, we move from Point B to Point C

At Point C, there are now two phases present, the liquid and solid sugar

This is because we have now exceeded the Solubility Limit at 100°C

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Criteria for solid solubility

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

	Crystal Structure	electronegativity	*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 suggesting high mutual solubility.

Ni and Cu are totally soluble in one another for all proportions.

So far, the term Solubility has been used to rationalise why different Phases are observed at a given Temperature and Composition

This makes a lot of sense when discussing systems such as the sugar-water system, where the solubility of sugar in water occurs through dissolving a solid in a liquid

But what about the solubility of one solid element in another, like in the case of alloys

The solubility of one element in another can be predicted by comparing the physical and chemical characteristics of each element

Let’s use the example of the simple Cu-Ni system

Both Ni and Cu have Face Centered Cubic crystal structures, and comparable electronegativities and atomic radii

Using this very simple assessment, Ni and Cu can be stated to have similar physical and chemical characteristics

Therefore, this might suggest they have a high mutual solubility

In practice, these two elements are totally soluble in one another at all Compositions of the alloy

When two elements form a single Phase, this is known as a Solid Solution

So if the physical and chemical characteristics of each of the Components are known, it may be possible to predict what the solubility of one component in another may be

From the predicted solubility of one component in another, a Phase Diagram can be calculated.

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Summary

- A phase is a physically and chemically distinct material formed by combination of two elements.
- Changing the temperature and/or composition can change the number of phases.

- In summary,
    - A Phase Diagram describes the different Phases observed when two or more Components are mixed together, as a function of the Composition and Temperature
    - A Phase is a material formed that has distinct physical and chemical characteristics
    - By changing the Temperature and/or Composition, the number and type of Phases observed can change
    - Because each phase has certain physical and chemical properties, a Phase Diagram can be used as a tool for designing specific materials for a given application

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Thank you

• This concludes the introduction to phase diagrams.

• If you have any questions or desire further clarification please post a question or comment on the ENR116 Discussion Forum.

• For further reading, please consult the course text, specifically chapter 9.