Solidification and Solid Solution

When a pure metal solidifies it changes from a liquid to a solid state. An intermediate state of liquid and solid exists (sometimes known as the pasty state). These states are known as **phases**, a **phase** being defined as regions that differ from one another, either in **composition** or in **structure** or in **both**. In a metal the **liquid state** consists of atoms randomly arranged whereas in the s**olid state** the atoms are arranged regularly in crystal lattices. Therefore the structure of the two states is different and is referred to as phases.

When a pure metal is cooled from the liquid state is produces a **cooling curve** as in figure 1. The change from the liquid to the solid state occurs at a definite temperature. Where solidification begins and finishes at the same temperature but the time increases. Examples of metals that have this are Lead, Copper, Aluminium. A pure metal solidifies at one fixed temperature, a fact which can be checked by plotting a **cooling curve**. A cooling curve may be obtained by melting a small amount of a metal and recording the temperature drop at suitable time intervals as this metal solidifies (the metal must be allowed to cool very slowly i.e. under equilibrium conditions) . We can then plot a graph of **(temperature-time)** to give us the cooling curve for that particular metal.

At temperatures above and below the curve falls smoothly without "kinks" . When the solidification temperature is reached, the temperature remains constant for some time thus giving rise to the step in the curve. Down to the temperature of the liquid drops in a regular manner as heat is being lost to the surroundings at a nearly constant rate. The step is due to **latent heat**. This leads to zero change in temperature until the last drop of liquid has solidified. After no more latent heat is available, the solid continues to cool in a regular manner giving the smooth curve.

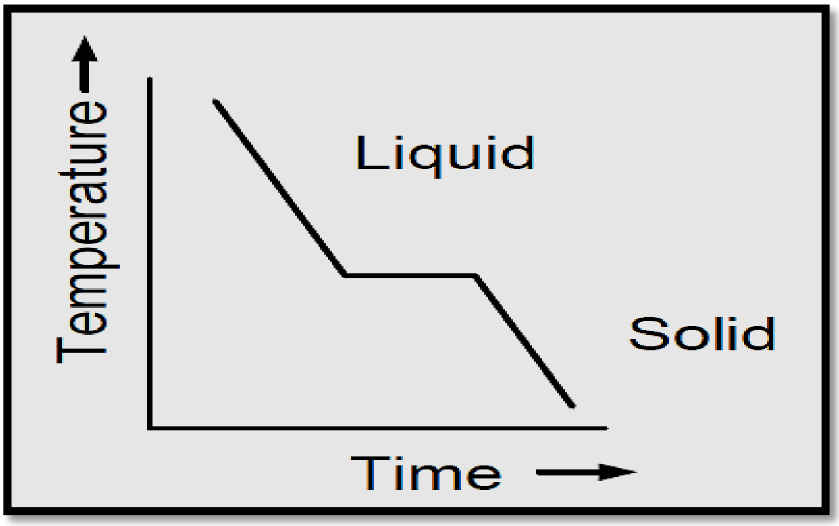

Figure 1. Cooling curve for a pure metal.

However during the cooling of an alloy the solidification occurs gradually (step by step) during a fall in temperature. An example of this would be (Copper-Nickel) creating a solid solution. This is depicted (shown) in figure 2**.** Unlike pure metals, alloys solidify over a range of temperatures. Below the temperature at which the alloy begins to solidify and the temperature when it is completely solidified the alloy is in a pasty state gradually becoming stiffer as the lower limit of the solidification range is approached. Therefore for any alloy there is a definite temperature at which solidification begins and an equally definite point where it ends. These two points are known as the **arrest points**. As two metals may be alloyed in many different compositions i.e. you could have **(80% A** and **20% B)** or **(60% A** and **40% B)** it stands to reason that the cooling curves for all these alloys will be different. Shown here are a selection of cooling curves for an alloy of Lead and Tin. Note that all alloys possess two arrest points with the exception of the 62% TIN alloy (tin mans solder). This alloy has only one single arrest point as the alloy does not go through a pasty state (like a pure metal) it goes directly from a liquid to a solid state .This is called the **Eutectic** alloy.

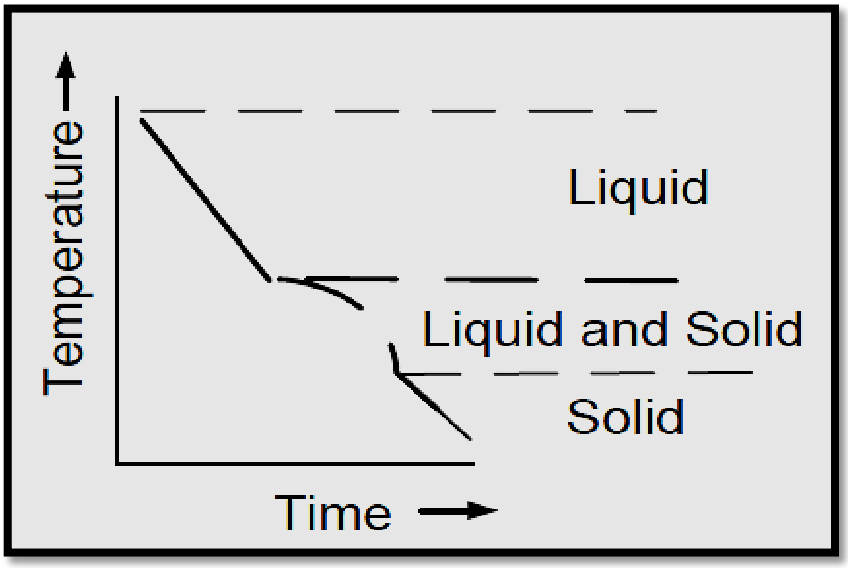

Figure 2. Cooling curve for an alloy.

Some alloys complete their solidification at a constant temperature and a curved temp./time as is shown in figure 3. Examples are (Cadmium and Bismuth) or (Lead and Tin) alloys.

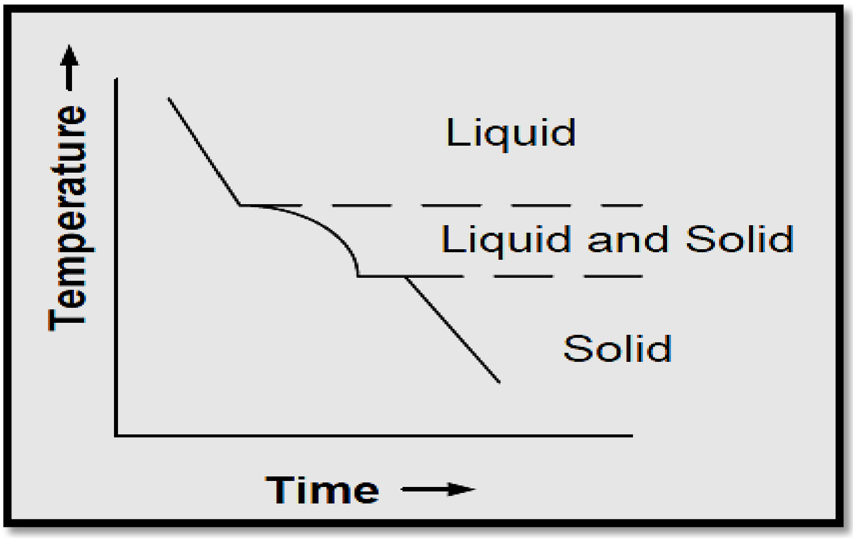

Figure 3. Cooling curves for some alloys.

Alloying Metals

Most pure metals are soft and not very useful in their pure state. There are of course exceptions i.e copper is an excellent electrical conductor in its pure state. Therefore in order to increase properties like strength, hardness and corrosion resistance we mix two or more pure metals together to give us an alloy. Everyday examples of alloys include **Bronze** which is an alloy of (**Copper** and **Tin**) where the Tin content is usually less than **20%**.

Solid Solution Alloys

A solid solution occurs when we alloy two metals and they are completely soluble in each other. If a solid solution alloy is viewed under a microscope only one type of crystal can be seen just like a pure metal. Solid solution alloys have similar properties to pure metals but with greater strength but are not good electrical conductors.

A. Substitutional Solid Solution

The name of this solid solution tells you exactly what happens as atoms of the parent metal (or solvent metal) are replaced or substituted by atoms of the alloying metal (solute metal). In this case, the atoms of the two metals in the alloy, are of similar size. Here we see the black atoms have been replaced or substituted by the white atoms in figure below.

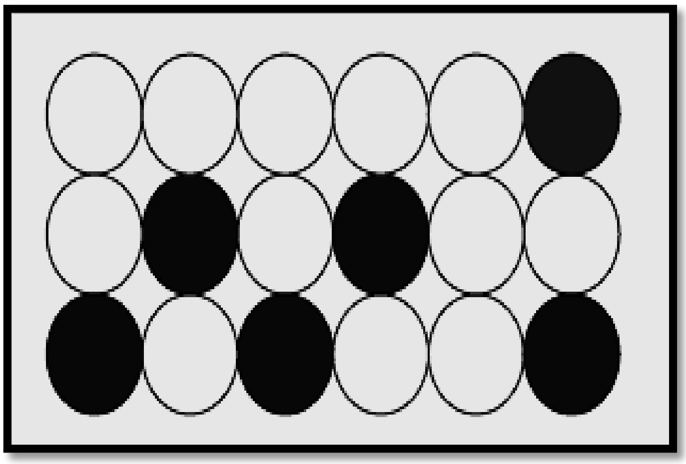

Figure 4. Substitutional Solid Solution.

B. Interstitial Solid Solution

In interstitial solid solutions the atoms of the (parent or solvent metal) are bigger than the atoms of the (alloying or solute metal). In this case, the smaller atoms fit (sit) into interstices (i.e. spaces between the larger atoms). The smaller atoms are small enough to fit into the spaces between the larger solvent atoms. Shown in figure below.

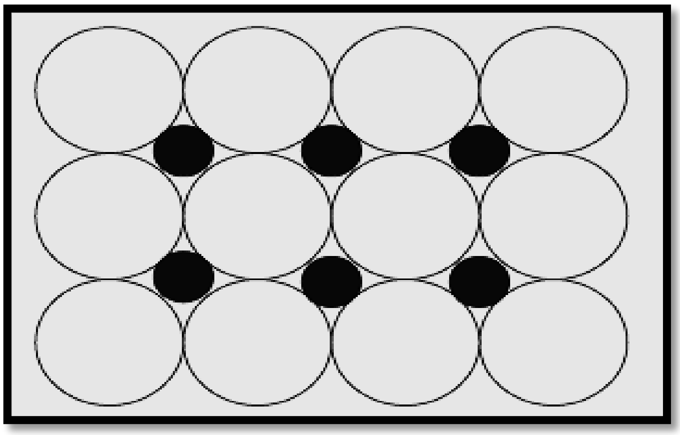

Figure 5. Interstitial solid solution.

In both substitutional and interstitial solid solutions the overall atomic structure is virtually unchanged. Examples of solid solution alloys include (Copper-Nickel), (Gold-Silver) all whom has an **FCC** structure. (Molybdenum-Tungsten) is an example of an solid solution with a **BCC** structure. Thermal diagrams created using solid solution alloys are given the name binary alloys.