6.2.2: Alloys and Intermetallics

When a molten metal is mixed with another substance, there are two mechanisms that can cause an alloy to form: (1) *atom exchange* or (2) *interstitial mechanism*. The relative size of each element in the mix plays a primary role in determining which mechanism will occur.

Substitutional Alloys

When the atoms are relatively similar in size, the atom exchange method usually happens, where some of the atoms composing the metallic crystals are substituted with atoms of the other constituent. This is called a *substitutional alloy*. Examples of substitutional alloys include bronze and brass, in which some of the copper atoms are substituted with either tin or zinc atoms.

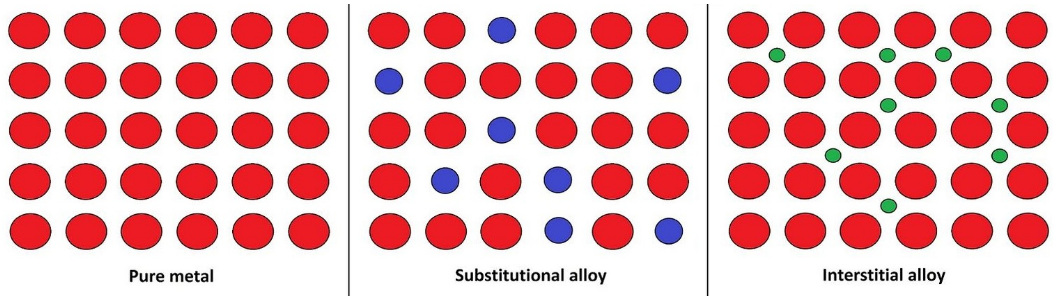

Figure 6.2.2.1: Different atomic mechanisms of alloy formation, showing pure metal, substitutional, and interstitial structures. (CCO; Hbf878 via Wikipedia)

Why Substitutional Alloys Occur: Bonding

The bonding between two metals is best described as a combination of metallic electron "sharing" and covalent bonding, one can't occur without the other and the proportion of one to the other changes depending on the constituents involved. Metals share there electrons throughout there structure, this flow of electrons is the reason behind many of the characteristics associated with metals, including their ability to act as conductors. The different amount and strength of covalent bonds can change depending on the different specific metals involved and how they are mixed. The covalent bonding is what is responsible for the crystal structure as well as the melting point and various other physical properties.

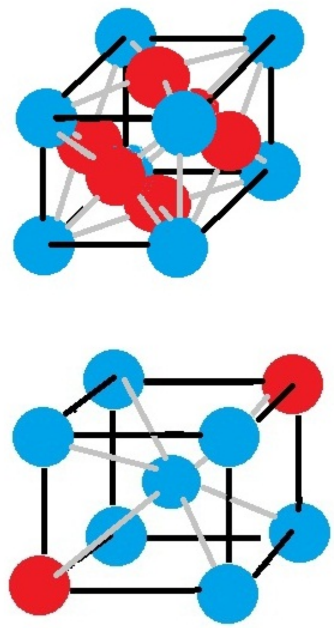

Figure 6.2.2.2: Examples of Substitutional Metal Alloys. Depending on the specific type of substitutional alloy they can have multiple crystal structures. Two of the possible structures include Face Center Cubic (left), and Cubic Center Cubic (right). The structure of the metal alloy is not limited to these two structures, but combined they represent a large portion of the common alloys.

As the similarities between the electron structure of the metals involved in the alloy increase, the metallic characteristics of the alloy decrease. Pure metals are useful but their applications are often limited to each individual metal's properties. Alloys allow metal mixtures that have increased resistance to oxidation, increased strength, conductivity, and melting point; Essentially any property can be manipulated by adjusting alloy concentrations. An example could be Brass Door fixtures, they are strong and resist corrosion better then pure zinc or copper, the two major metals that constitute a brass alloy. The combination also has a low melting point allowing it to be easily cast into many different shapes and sizes.(1) There are many other aspects of substitutional alloys that could be explored in depth, but the basic concept is the idea that each individual metal in an alloy give the final product its chemical and physical properties.

Substitutional alloys played an important role in the development of human society and culture as we know it today. The Bronze age itself is named after the Substitutional alloy consisting of tin in a metallic solution of copper. Ancient bronzes are very impure, or even mislabeled, containing large amounts of zinc and arsenic as well as lots of impurities. These many substitutional alloys allowed for stronger tools and weapons, they allowed for increased productivity in the workshop as well as on the battlefield. The need for raw materials like tin and copper for the production of bronze also spurred an increase in trade, since their ores are rarely found together. The current chemical understanding of substitutional alloys would not be so in depth if it weren't for the usefulness of the alloys to humans.

Interstitial Alloys

With the interstitial mechanism, one atom is usually much smaller than the other, so cannot successfully replace an atom in the crystals of the base metal. The smaller atoms become trapped in the spaces between the atoms in the crystal matrix, called the *interstices*. This is referred to as an *interstitial alloy*. Steel is an example of an interstitial alloy, because the very small carbon atoms fit into interstices of the iron matrix. Stainless steel is an example of a combination of interstitial and substitutional alloys, because the carbon atoms fit into the interstices, but some of the iron atoms are replaced with nickel and chromium atoms.

Intermetallics

Intermetallic compounds are solid phases containing two or more metallic elements, with optionally one or more non-metallic elements, whose crystal structure differs from that of the other constituents.

Summary

An alloy is a mixture of metals that has bulk metallic properties different from those of its constituent elements. Alloys can be formed by substituting one metal atom for another of similar size in the lattice (substitutional alloys), by inserting smaller atoms into holes in the metal lattice (interstitial alloys), or by a combination of both. Although the elemental composition of most alloys can vary over wide ranges, certain metals combine in only fixed proportions to form intermetallic compounds.

References

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3. Dickinson, O. T. P. K. (1994). *The Aegean Bronze age*. Cambridge world archeology. Cambridge: Cambridge University Press.

Problems

1. Are substitutional metal alloys naturally occurring on earths surface?
2. What are two characteristics of a metal required for a substitutional alloy to form?
3. Can Oxygen or Nitrogen be a part of the crystal structure of a substitutional alloy?

Solutions

1. No, the oxidizing nature of the earths atmosphere, as well as the need for specific and concentrated metals keeps these from being found naturally occurring.
2. Similar radii and similar electronegativity.
3. Only metallic elements can form the necessary metallic bonds that allow alloys to form.