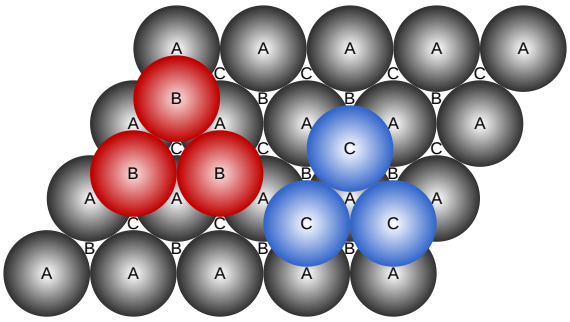
Metal Crystal Structures

Skills to Develop

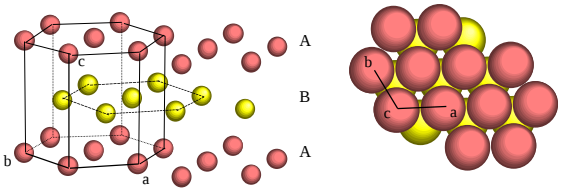
- Describe the different types of unit cells and alloys

Most metals want to have high coordination numbers (lots of neighbors for each atom). The highest coordination number possible with spheres is 12. There are 2 regular arrangements that give 12 neighbors, and they are called **close-packing**. These are the densest possible ways to arrange spheres. Both are based on hexagonal planes of atoms that are stacked. Each plane's atoms sit in the holes of the lower plane. Look at the figure.



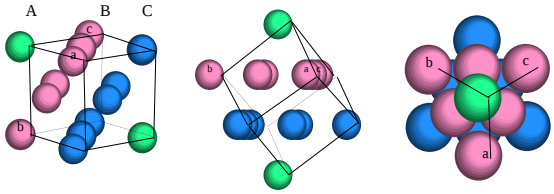
by Life of Riley via Wikimedia Commons

The gray A spheres represent the bottom plane. The holes in this plane are labelled B and C. The next layer will go over either the B holes or the C holes. It doesn't matter which. The 2 types of close-packing come from what happens to the third layer. If the layers are ABAB (which is equivalent to ACAC or BCBC), that forms one type of close packing, called **hexagonal close-packed**, or hcp. The other type of close packing has layers ABCABC and is called **cubic close-packed** or ccp. Cubic close-packed is also called **face-centered cubic** or fcc because it is a cubic structure with an atom on each face and corner of the cube. Each atom in a close-packed structure has 12 neighbors (6 in its plane, and 3 in the planes above and below).



hexagonal close-packed (hcp) ABAB

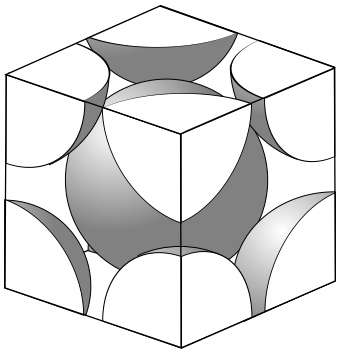
A layer atoms are in red and B layer atoms are in yellow. Notice that the overall arrangment makes a hexagonal structure (lattice vectors are labelled a,b,c). By Maghemite via Wikimedia Commons.



cubic close-packed (CCP) ABCABC

A layer atoms are in green, B layer atoms pink and C layer atoms blue. Notice that the overall arrangment makes a cubic structure with atoms on the corners and faces of the cube (lattice vectors are labeled a,b,c). By Maghemite via Wikimedia Commons.

Not all metals make close-packed structures. A few have a **simple cubic structure** (just one atom on each corner of the cubic unit cell), so in this case each atom has a coordination number of 6. Another more common structure is called **body-centered cubic** or bcc, in which there is an atom on each corner and in the center of the cubic unit cell, so that each atom has 8 neighbors. Here's a different view of the bcc unit cell, using a "space-filling" picture of the atoms. Notice that each corner of the unit cell actually has 1/8 of an atom. (If there were a whole atom on each corner, then we'd get the wrong structure when we stack the unit cells.)



Space-filling view of the bcc unit cell, by Cdang and Samuel Dupre, via Wikimedia Commons.

Alloys

Alloys are metal solutions or compounds. Some alloys have different metal atoms arranged in a regular structure. These alloys have a precise formula, such as Ni_3Al. Others have a random replacement of one type of metal atom with another, like gold/silver alloys. Both gold and silver have the fcc/ccp structure and the atoms are similar sizes, so they can make mixtures with almost any % Au and Ag. This is called a **substitutional alloy** because one type of atom substitutes for another. A third type have a smaller atom (like carbon in steel) that occupies some of the holes between the majority metal atom. This is called an **interstitial alloy**. Alloys are important for many applications because they have different properties compared to the pure metals.

Outside Link

- CrashCourse Chemistry: Doing Solids (11 min)

Contributors and Attributions

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