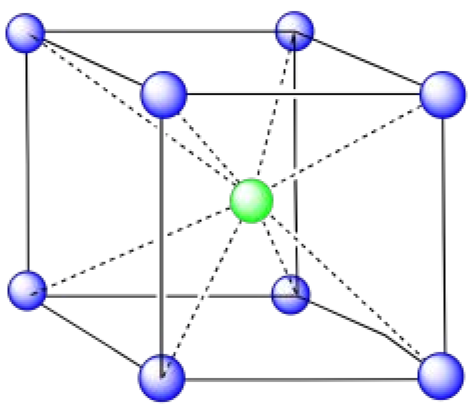
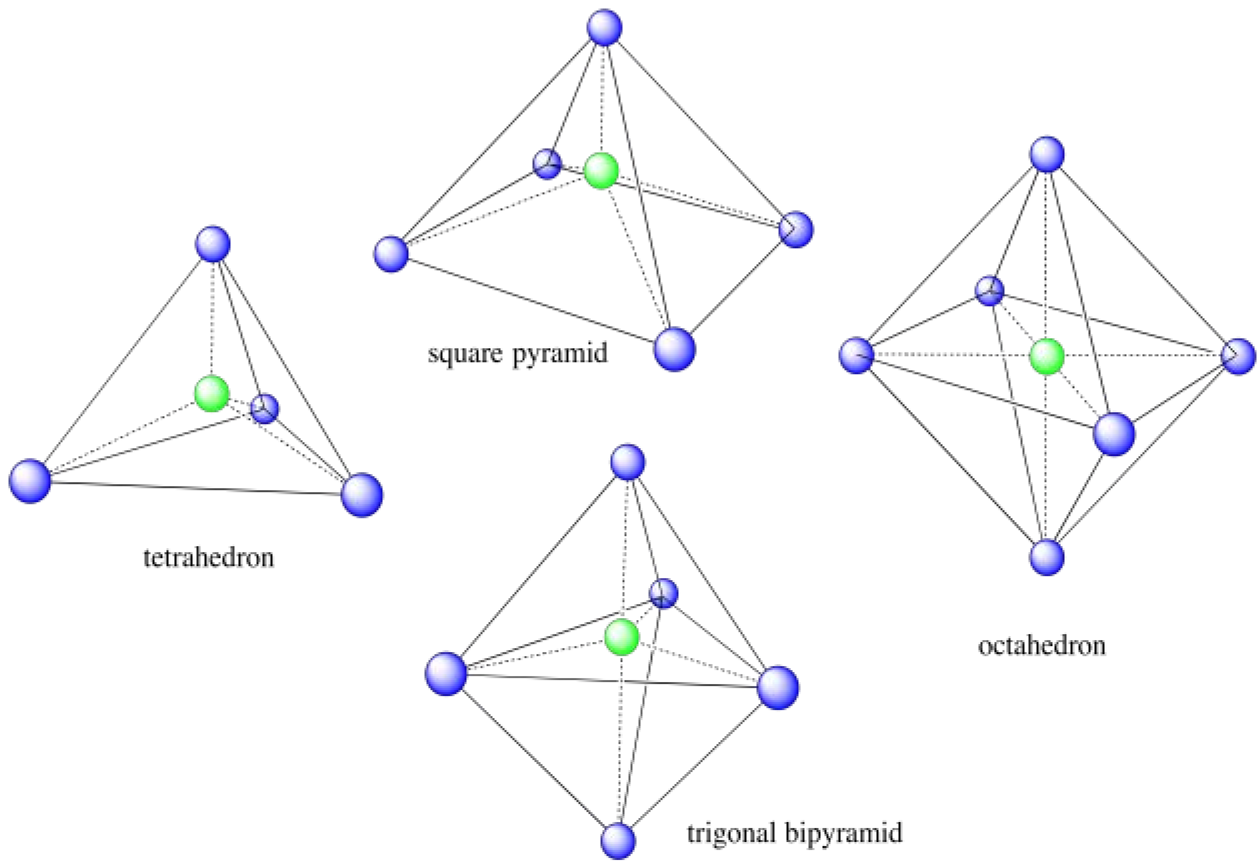
BUILDING METAL ATOMS IN THREE DIMENSIONS

What sort of structures compose the world around us? What sort of shapes do we see in the building blocks of the material world? The ancient Greeks placed special significance on certain perfect shapes, or Platonic solids. These shapes were considered to be perfect because they were so regular, with equally sized sides arranged at identical angles to each other, so that the solid would look the same when viewed from different angles. For example, a cube has four square sides, all connected at right angles to each other. These Platonic solids were sometimes associated with the classic elements as perceived at the time: earth, air, fire and water.



As it happens, the Greeks were not that far from the truth. Certain solids do appear frequently in the structures of nature, including the classic Platonic solids. These shapes just happen to describe the natural way that a group of atoms might arrange themselves when they come together to build a larger structure. Very often, we find an atom at the center of a Platonic solid, with other atoms arranged around it to form the corners of the solid.

In addition to the cube shown above, the tetrahedron and octahedron are extremely common Platonic solids found in natural structures. A couple of non-Platonic solids that we sometimes see are the square pyramid (think of the ones in Egypt) and the trigonal bipyramid; however, we won't encounter those in nature for a few more chapters.



Problem ME3.0.

For each of the following solids, identify the number of (i) corners and (ii) faces.

a) cube b) tetrahedron c) square pyramid d) trigonal bipyramid e) octahedron

We will see cubic, octahedral and tetrahedral shapes cropping up as we look at the structures of extended solids such as metals and salts. In the solid state, metals are very neat, orderly structures. Metal atoms form a three-dimensional, crystalline structure. We will start thinking about those structures by seeing how they can be built up from simpler, two-dimensional layers.

Building up from Squares: Simple Cubic Packing

Take a simple square layer of atoms. Suppose another layer forms on top of that one, with atoms arranged in the same way as the first layer. Each atom in the second layer sits directly on top of an atom in the first layer.

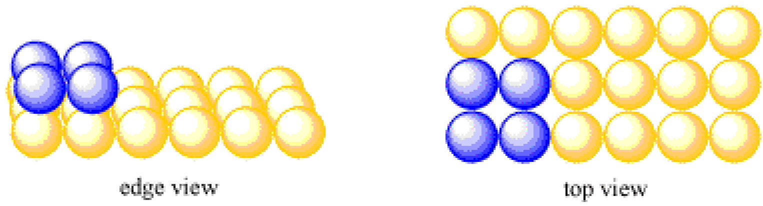


Figure ME3.1. Adding a second layer of atoms to a simple square layer.

This is a very neat, ordered, simple structure. All of the atoms are lined up in straight rows, aisles and columns. The structure looks exactly the same if viewed along the x-axis, along the y-axis, or along the z-axis.

The simplest repeating unit in three dimensions is usually thought of as a box or cube with atoms at each of its eight corners. Alternatively, we might think of the repeating unit as a cube with one atom in its center. However, it's useful to see the relationships between multiple atoms in the unit cell. For that reason, we usually picture the unit cell as the cube with an atom at each corner. Because each of those corners is shared between several unit cells, it is better to think of each unit cell as only owning a fraction of each corner atom.

- A simple cubic unit cell is based on a square layer.
- Squares of atoms are repeated in the x, y and z directions.

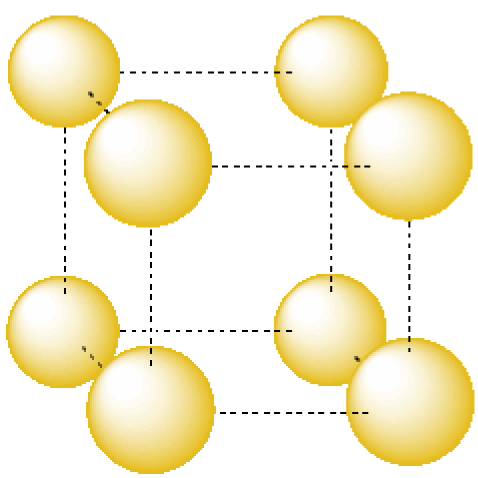


Figure ME3.2. A simple cubic unit cell. The atoms are separated so that you can see their relationship more clearly.

In the following sections, unit cells will be shown with atoms separated even further from each other because the relationships between the atoms are even more complex. In the case of a simple cubic packing system, the unit cell would be shown as follows:

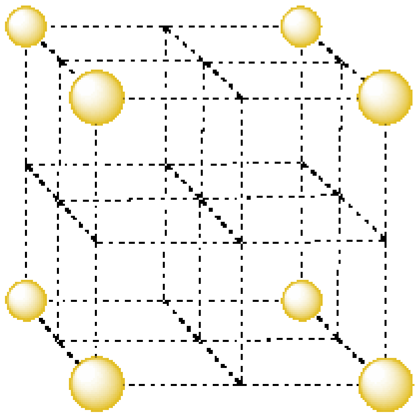


Figure ME3.3. A simple cubic unit cell. The atoms are separated so that you can see their relationship more clearly.

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