Unit 1, Lesson 13: Classifying Solids

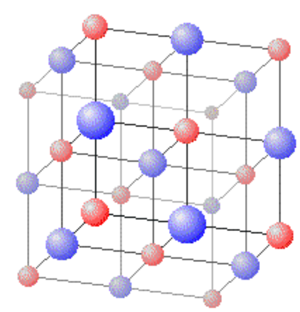
So far in this unit, we have been talking about the chemical formulas, shapes, and polarities of small molecules, and how these factors affect the physical properties of a substance, such as its melting point, boiling point and hardness.

Recall:

1. **Non-polar molecules** are attracted to one another only by dispersion forces. These are very weak inter-molecular attractions so non-polar molecules have very low melting and boiling points. These molecules must be cooled to very low temperatures before they will solidify.
   eg. CO_2, CH_4, CF_4, H_2, N_2, O_2
   Larger non-polar molecules have larger numbers of electrons, so they will have larger dispersion forces and slightly higher melting and boiling points. Large hydrocarbon molecules like paraffin wax ($C_{24}H_{50}$) are solids at SATP. Their long, linear molecules allow sufficient dispersion forces to hold the molecules together.

2. **Polar molecules** are attracted to one another by dispersion forces and dipole-dipole attractions. These are fairly strong inter-molecular attractions, so polar covalent molecules have moderate melting and boiling points.
   eg. H_2O, CH_3OH, CH_3COOH, NH_3
   Larger polar molecules will have higher melting and boiling points.

3. **Ionic substances** are attracted to one another by dispersion forces and full ion-ion attraction. These are extremely strong inter-molecular attractions. Ionic substances have very high melting and boiling points.
   eg. NaCl, MgO, $CaCl_2$, Al_2S_3
   Ionic substances will arrange themselves into a solid crystal lattice structure that has the lowest possible energy. Depending on the sizes of the ions involved, and the ratio of positive and negative ions, the crystal lattice may have different lattice structures.



a) If the positive ions are approximately the same size as the negative ions and the ratio of positive to negative ions is 1:1, then the crystal will probably take on a simple cubic arrangement. A small piece of this crystal will be a "face-centred cube", similar to what we saw in Lesson #6, metallic bonding.

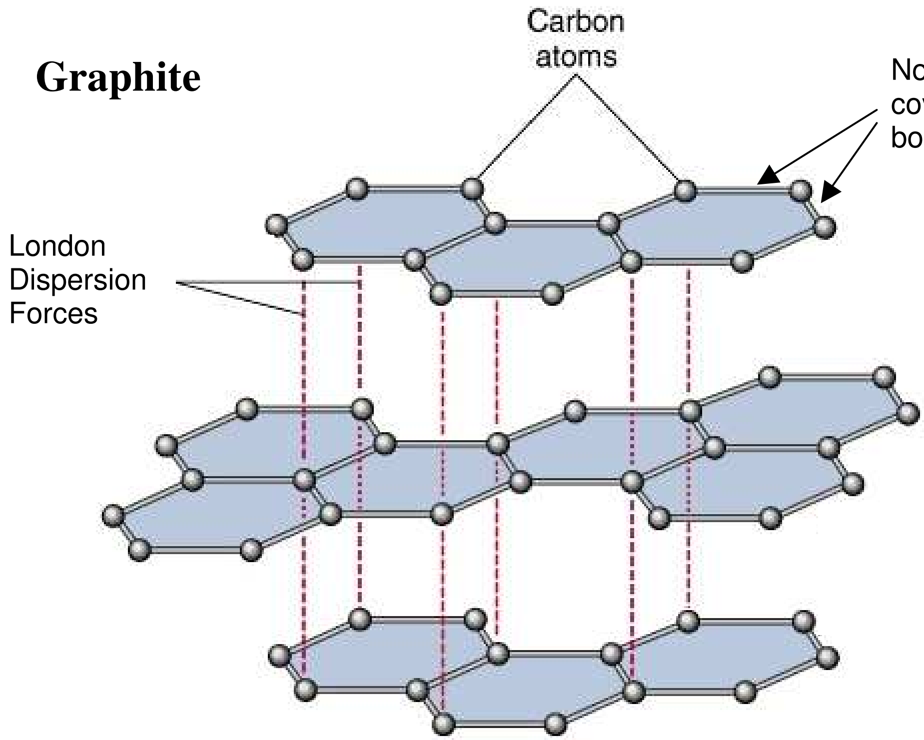
b) If one of the positive or negative ions is much larger than the other, then the crystal will take on a different arrangement, perhaps a body-centred cube or a hexagonal crystal structure.

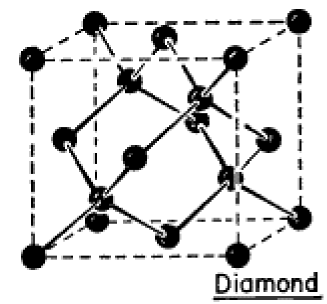
4. Network Solids

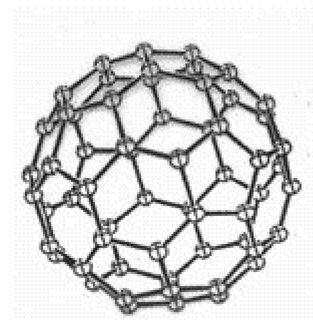
There is a fourth type of solid structure called a network solid. Network solids usually involve Group IV elements. In a network solid, all of the atoms are ***covalently bonded*** to each other to form giant 2–D or 3–D molecules. The most common example of a network solid is diamond- a huge molecule that is made up of a network of carbon atoms all bonded to one another in three dimensions. There are no inter-molecular attractions in diamond because the diamond is technically one huge molecule.

Depending on how the atoms in the network solids are arranged, they can have extremely different properties, even when their chemical composition is identical. Different forms of the same element that have different chemical and physical characteristics are called "**allotropes**". Carbon has many different allotropes, including diamond, graphite and buckminsterfullerene, depending on how the carbon atoms are bonded to one another.

Allotropes of Carbon







Buckminsterfullerene
(bucky balls)

Compounds can also form network solids- huge molecules that are bonded in three dimensions. For example, the common mineral quartz is a network solid made up of SiO_2, bonded in three dimensions.

Properties of Network Solids
Because network solids are such huge molecules with bonds in so many directions, they tend to:

- have very high melting and boiling points
- have very poor solubility in water
- are poor conductors of electricity because there are few delocalized electrons (graphite is the exception to this rule, there are delocalized electrons between the 2-D sheets of the network, and these electrons can conduct an electric current)

5. Amorphous Solids
The final type of solids that should be mentioned are amorphous solids- these are solids that have no organized crystal structure ("a" in front of a word means "without", and "morph" means "form or shape"). Examples of amorphous solids include glass- it does not form crystals when it cools and solidifies, and many polymers such as rubber. Amorphous solids are too diverse a group to be able to discuss "typical" properties.

Homework:

1. Read pages 196 to 199, and page 204
2. Answer questions 3 and 5 on page 208
3. Complete the chart "Summary: Characteristics of Crystalline Solids" to compare the properties of the different types of crystalline solids (solids that have a regular crystal structure)