4.6 The Structure and Properties of Solids

- Solids behave differently based on their intermolecular bonding.
- Classifications of Solids:
  - Ionic — metal + nonmetal — NaCl
  - Metallic — metals — Cu
  - Molecular — nonmetal molecules — H_2O
  - Covalent network — metalloids/carbon — C (graphite or diamond)

Ionic Crystals

- Ionic bonds in a crystal lattice (3d arrangement) - ions held together
- Solids are do not conduct electricity, brittle due to the strong bonds, can have a variety of shapes, high melting point, will conduct electricity when dissolved in water.
- Why? → ionic bonds are strong and directional
- The properties of ionic crystals are explained by a dipole-dipole arrangement of positive and negative ions held together by strong, directional ionic bonds.
- E.g. Salt (NaCl)

Metallic Crystals

- Positive kernels in a sea of electrons.
- Solids that are shiny, silvery, flexible with good electrical and thermal conductivity. Hardness, melting point and boiling point varies.
- Why? → Current Theory: the properties are the result of the bonding between fixed, positive nuclei and loosely held, mobile valence electrons. The electrons act as a "negative glue" holding the positive nuclei together.

- The properties of metallic crystals are explained by a 3-D arrangement of metal cations held together by strong, non-directional bonds created by a "sea" of mobile electrons.
- E.g. Rice crispy square.

Molecular Crystals

- Molecules are held together by intermolecular forces.
- Have low melting point, not very hard, non-conductors of electricity in their pure form or in solution, for a lattice that can be more complicated.
- Held together by dipole-dipole force, London forces, and hydrogen bonding…which are weak compared to the ionic or covalent bonds.
- Why? → these are solids composed of a collection of individual molecules held weakly together.
- The properties of molecular crystals are explained by a 3-D arrangement of neutral molecules held together by relatively weak intermolecular forces.
- E.g. $I_{2(s)}$ or $CO_{2(s)}$

Covalent Network Crystals

- These are crystals that have covalently bonded molecules or atoms. E.g. Diamond is $C_{(s)}$ whereas; quartz is $SiO_{2(s)}$.
- They are very hard, brittle, very high melting points, insoluble, nonconductors of electricity.

- Covalent bonds can be 1-D, 2-D or 3-D depending on the material and some are both. E.g. 1-D asbestos, 2-D graphite (C), 3-D diamond (C).
- Why? → the covalent bond within the molecule is strong and the network bonds create a very strong crystal…stronger than ionic crystals.
- The Properties of network covalent crystals are explained by a 3-D arrangement of atoms held together by strong, directional covalent bonds.
- E.g. Diamond

Other Covalent Networks of Carbon

- Carbon bonds well to itself to produce sheets (graphite), tetrahedrally (diamonds), spheres (buckyballs), tubes (nanotubes)
- Graphite is of interest because it is a lubricant (weak bonding between sheets) and it conducts electricity (mobile π bonds)

Semiconductors

- Usually made of silicon but "doping" with group 13 or 15 elements that allow for a selected conductance.

Homework

- Practice 1,2,3,4,5,6,7