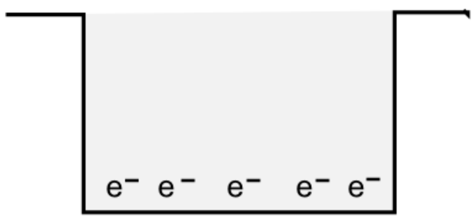
Topic 1-2: Dipole Interactions
Kittel Pages: 69, 49-56, 70

Summary: Metallic bonding is briefly introduced and related to the electron in a box model. Next, we move to dipoles where we discuss dipole interactions of non-polar molecules as well as London dispersion forces, Van der Waals bonds and hydrogen bonding.

Metallic Bonding

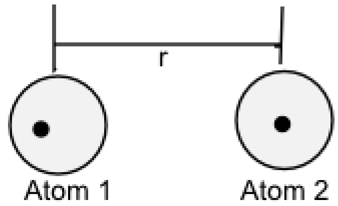
- Piece of metal contains electrons throughout; to first order can ignore electron-electron interactions (Pauli exclusion principle still holds, however)
- Can treat electrons like a free gas
  - Particle in a box model



- No requirement for periodicity of nuclei. However, in practice most metals are crystalline (periodically ordered nuclei)
- Not really a classical "bond"
  - Really, just a balance between attractive and repulsive coulombic forces

Dipole Interactions

- Dipoles can lead to intermolecular forces
- Consider nonpolar molecule; 'nonpolar' implies that the time averaged dipole is zero, $\langle d \rangle = 0$
  - However, random quantum fluctuations can generate a spontaneous dipole at some time t



- The electric field at atom 2 is as in equation 1 below where d_2 is the induced dipole

$$\frac{d_1}{r^3} = d_2 \qquad [1]$$

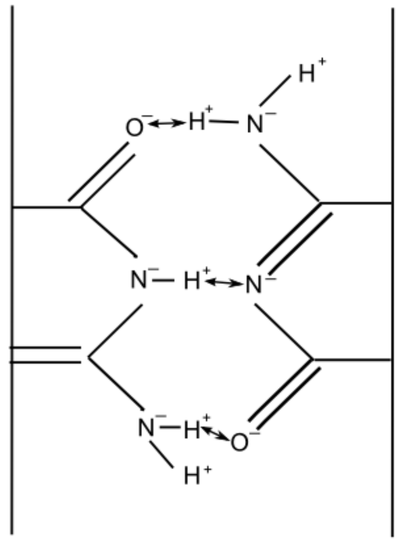
- The energy of this interaction is:

$$-\frac{d_1 d_2}{r^3} \qquad [2]$$

- Plugging in our expression for d_2 we get the energy to be proportional to $-\frac{{d_1}^2}{r^6}$. So while $\langle d_1 \rangle = 0$, there is an attractive force between atoms 1 and 2 arising from this spontaneous dipole/induced dipole interaction.
- London dispersion force: temporary attractive force created when adjacent atoms form temporary dipoles
    - Weakest intermolecular force
- This force forms Van der Waals bonds: bonds created by dipole interactions
    - Occurs in every interaction but are usually *overshadowed* by stronger bonds like covalent bonds
    - Requires extremely close atoms because of r^{-6} term

Type	Dissociation energy (kcal/mol)
Ionic	400
Hydrogen	12-16
Other dipole-dipole	0.5-2
Van der Waals	<1

- Hydrogen bonds: strong dipole-dipole interactions



- Examples of breaking bonds
  - Egg- cooking breaks lower energy *configurational* dipole-based bonds in proteins. This re-arrangement of protein structure which causes white color. Temperature is not hot enough to break covalent bonds.
  - Silicon- takes a lot of heat to melt (mp = 1,414C) because you must break strong covalent bonds

Questions to ponder

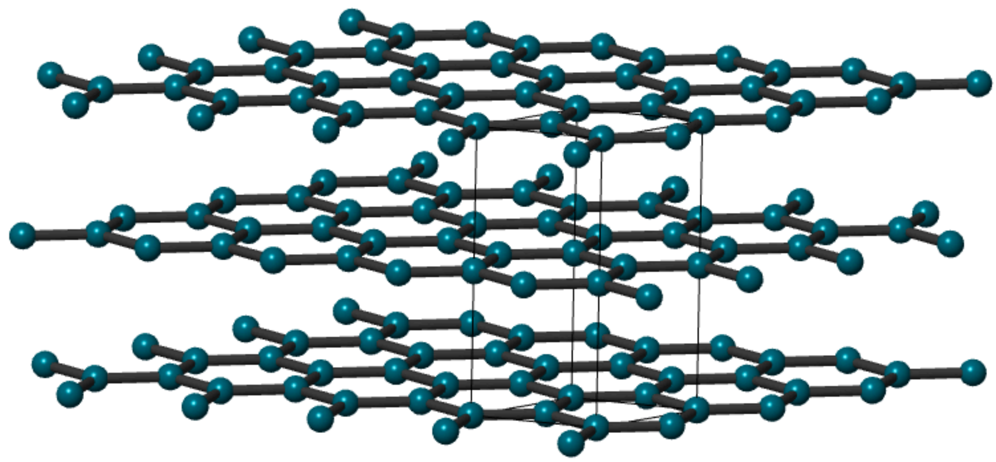
1. How do you identify Van der Waals bonds experimentally?

2. How do geckos walk on walls?

3. How do metals permanently deform?

4. Why do certain metals have particularly low melting points?

5. The crystal structure of graphite is shown below. Where are there van der Waals bonds in this structure?



6. The crystal structure of $SiSe_2$ is shown below, shown (a) down the chains and (b) a single chain. Describe the bonding in this compound.