3. The Metallic Bonding

Electron mobility explains metals high electrical conductivity and thermal conductivity. Lack of directionality explains high deformability of metals. Homework: Investigate what the Wiedemann-Franz law is.

The Metallic Bonding (cont.)

- Delocalized electrons
- Strong Bonds
- Geometric Arrangements
- Compact Arrangements
- Deformable Solids
- Silverish Color

Examples:
- **FCC**: Face-Centered Cubic
- **HCP**: Compact Hexagonal
- **BCC**: Body-Centered Cubic
4. Secondary Bonding (van der Waals)

The van der Waals force is electrostatic. Bonding result from small quantum fluctuations in the charge which induce electric dipole moments.

Question: How would the atomic number of an inert gas affect the strength of the bond (or \( E_{\text{bond}} \))? 

Secondary Bonding (cont.)

Permanent dipoles

Strong covalent bonds bind two atoms of hydrogen (white balls) to an atom of oxygen (red balls) to form a molecule of \( \text{H}_2\text{O} \). Hydrogen bond, glues groups of water molecules together. Hydrogen bonds are principally the electrical attractions between a positively charged hydrogen atom—which readily gives up its electron in water—and a negatively charged oxygen atom—which receives these electrons—in a neighboring molecule.
Recent Discovery

In 2001 researchers confirmed the controversial prediction of Linus Pauling that hydrogen bonds between water molecules would also be affected by the covalent bonds within the water molecules and would partially assume the identity of those bonds.

The structure of ice is regulated by the orientation of the dipoles

Two different types of bond intervene
This geometric pattern is due to the dipolar molecules orientation and their growth

Frost on windshields experience certain growth patterns too, called dendrites.
Notice the directions of ice growth. Every crystalline material tends to follow a specific spatial direction when it condenses.

One word about “polar moment” in a covalent molecule
Consider that H is much less electronegative than C and N and answer the following:

What is the difference between these two molecules and the other three?

Homework: Investigate and compare the following polar molecules HF, HCl, HBr & HI
We’ll use the concept of permanent dipoles to explain the diverse strengths of polymers

**Polymers (Chapter 16)**

- Consider the structure of ethylene with covalent $\pi$ bond between C atoms:

- Free radical polymerization breaks the $\pi$ bond to form $\sigma$ bond…

- The $\sigma$ bonds link the “mer” with other “mers to form a chain.

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We’ll use PE to define the characteristics of a THERMOPLASTIC

- The chains (macromolecules) can easily tangle up, which are somewhat untangled by applied tensile forces
- They can be amorphous (no geometric pattern) or crystalline
- They soften and melt by applying heat
- They can be easily shaped to form a part.
- They are quite recyclable
- The degree of polymerization regulates the melting point

Note the formation of secondary bonds between chains

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Another exam Polypropelene
Permanent dipole concept explains the higher strength of PVC

Polyvinyl Chloride (PVC) molecules

Note that there is an additional contribution of the stronger Van der Waals bonds to the strength of PVC compared to PE

As a result, PVC has a high melting point: 212°C

Now let’s explain the main properties of a THERMOSETTING POLYMER

Consider now the hydrocarbon rubber structure

- Originally it contains double links
- Open one of them and incorporate a sulfur atom → a crosslink!
- Now it won’t melt!

Mechanical properties of elastomers depend strongly on the nature of the crosslinks. Sec. 15.9, pages 541-543.
More on elastomers

Vulcanization takes place simultaneously with molding. Important variables in the process:
- time before crosslinking starts.
- rate of crosslinking formation
- number of crosslinking formed

First, crosslinking should be retarded to give time for good mixing. Rate of crosslinking can be controlled by accelerators. Final properties depend on the number of crosslinks.

Read carefully: Section 16-8 in the textbook (pages 591-596)

Reading Assignment 1: Polymers

Chapter 16 (pages 563-568, 572-580, 591-598)
Sections 16.1, 16.3, 16.5, 16-8 and 16.9
Solve the following example problems: 16-4 and 16-5
After reading you should be able to:
- Describe the polymerization process
- Calculate the molecular weight of a polymer or a mer.
- Define stereoisomerism
- Classify copolymers Homopolymer (AAAAAAAAAA); Random (CACBAABAA); Alternating (ABCABCABCA); Block (AAABBBBBCCCC); Graft
- Describe thermoplastic elastomers.
- Provide examples of common thermosets
- Answer the following questions (not in the book): How are melting points related to molecular weight in linear, simple polymers? Why?
Let’s present a little more on the mixed nature of bonds in some metals

The strange case of the transition metals: metallic bonding + a covalent component → Look at the Melting Points!!

Remember that this tight, mixed bond is also reflected in the thermal expansion coefficients (pages 791-792)

More on the mixed nature of bonds in some compounds

• Homework:

Please try to explain this image on the influence of electro-negativity difference on the percent of ionic nature of the bonds. Then find the melting points of those compounds and try to establish a trend that relates melting points and percent of ionic character
Bonding energies are related not only to the nature of the bond but also to melting points of pure substances.

<table>
<thead>
<tr>
<th>Bonding Type</th>
<th>Substance</th>
<th>Bonding Energy</th>
<th>Melting Temperature (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ionic</td>
<td>NaCl</td>
<td>640 (153)</td>
<td>801</td>
</tr>
<tr>
<td></td>
<td>MgO</td>
<td>1000 (239)</td>
<td>2800</td>
</tr>
<tr>
<td>Covalent</td>
<td>Si</td>
<td>450 (108)</td>
<td>1410</td>
</tr>
<tr>
<td></td>
<td>C (diamond)</td>
<td>713 (170)</td>
<td>&gt;3550</td>
</tr>
<tr>
<td>Metallic</td>
<td>Hg</td>
<td>68 (16)</td>
<td>-39</td>
</tr>
<tr>
<td></td>
<td>Al</td>
<td>324 (77)</td>
<td>660</td>
</tr>
<tr>
<td></td>
<td>Fe</td>
<td>406 (97)</td>
<td>1538</td>
</tr>
<tr>
<td></td>
<td>W</td>
<td>849 (203)</td>
<td>3410</td>
</tr>
<tr>
<td>van der Waals</td>
<td>Ar</td>
<td>7.7 (1.8)</td>
<td>-189</td>
</tr>
<tr>
<td></td>
<td>Cl₂</td>
<td>31 (7.4)</td>
<td>-101</td>
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<tr>
<td>Hydrogen</td>
<td>NH₃</td>
<td>35 (8.4)</td>
<td>-78</td>
</tr>
<tr>
<td></td>
<td>H₂O</td>
<td>51 (12.2)</td>
<td>0</td>
</tr>
</tbody>
</table>

So, what does this tell us about the physical meaning of melting points?