Solids

Ron Robertson

The Solid Phase

A. **True solids can be visualized as a repeating pattern called a crystal lattice.**
   - **This pattern may be composed of ions, atoms or molecules.**
   - **The pattern is composed of unit cells.**
   - **There are 7 basic patterns for unit cells.**
   - **There are 3 basic arrangements of particles for each of the 7 patterns - simple, body-centered and face-centered - thus there are 21 possible arrangements.**
   - **The type of arrangement and the forces holding the particles in the arrangement determines the properties of the solid.**

B. Forces holding particles in crystal lattice

Name	Example	Particle type	Force
ionic	NaCl	+ and - ions	electrostatic
metallic	Fe, Cu, etc.	metal atoms	sharing of high energy electrons
molecular and atomic	H_2, CO_2, Xe, CH_3OH	molecules and atoms	Van der Waals (dipole/dipole and dispersion)
network	diamond, quartz	atoms	covalent bonds
amorphous (false solids)	glass, plastics	molecules	covalent or van der Waals

Examples

A. **General properties for selected molecules**

1. **H-bonding and water**
- **Each water molecule is H-bonded to another molecule and is arranged in a hexagonal crystal lattice**
- **This causes expansion when changing from liquid to solid.**

2. **Phase changes and energy changes**
- **Substances with high intermolecular forces have high MP and BP and high heat of fusion and heat of vaporization.**
- **Melting is endothermic, freezing is exothermic**

3. **Phase changes and pressure**

- **Some substances have such a high VP that they go directly from solid to gas (sublimation). CO_2 is the best example but ice also sublimes.**
- **Phase Diagrams for water and carbon dioxide**

B. Metals

1. Properties

- **High electrical conductivity**
- **High thermal conductivity**
- **Ductility and malleability**
- **Luster**
- **Insolubility in water**

2. Bonding

Metal bonding is complex. In order to truly understand it we have to employ the highest level of thinking about the bonding process - a model called molecular orbital theory.

In this theory we envision atoms bonding because they overlap and share all their electrons in various ways. Metals bond because all the atoms share in an unusual way their outermost, high energy electrons. The sharing is delocalized, not just between two atoms. Conduction band theory is the name for the application of MO theory to metals.

3. **[Diagram of metal, insulator and semiconductor conduction bands]**

   Conduction takes place when electrons are caused to move into the conduction band. This is very difficult for insulators, less difficult for semiconductors and easy for metals.

C. Graphite and diamond (allotropes of carbon)

1. **Graphite**
   consists of sheets of 6 membered rings held together by weak dispersion forces. The sheets move easily and it is used as a lubricant.
2. **Diamond**
   consists of one giant molecule where every carbon atom is covalently bonded to another. Diamond is more dense than graphite.

D. SiO_2 - silica

1. **Common compound found in many rocks (a mineral)**
2. **Forms chain of SiO_4 (silicates) that give great diversity. There chains can lay side by side and form fibers. Asbestos is a good example.**
3. **The sheets of SiO_4 give rise to clays in which some Si^{+4} ions are replaced by Al^{+3}. Clays belong to a general class of compounds called <u>aluminosilicates</u>.**

E. Ceramics

- **a general term used to describe substances made by baking nonmetal compounds.**

1. **silicate ceramics - water hydrates the silica sheets and allows the "clay" to be molded. Driving off the water hardens the structure as new Si-O-Si bonds form.**

2. **Oxide ceramics - the properties of Al_2O_3 and MgO change as they are heated as the individual unit cells link together.**

F. Glass

- **an amorphous solid formed from oxides of SiO_2, B_2O_3, GeO_2, and P_4O_{10}**

1. **Glasses are not true solids due to the fact that they do not have a regular arrangement**
2. **Common glass is SiO_2 + Na_2O + either CaO, MgO or Al_2O_3. This reduces the melting point of the mixture and keeps the glass resistant to chemical attack.**

G. Liquid crystals

- **flow like liquids but have a high degree of order**
- **are considered mesomorphic materials - between liquid and solid**
- **are composed of long rod-like molecules**
- **have optical and electrical anisotropy**

How does molecular order affect physical properties?

- **Isotropic - physical properties are the same in every direction (true for gases and most liquids)**
- **Anisotropic - properties depend on the orientation of the molecules (solid and liquid crystals)**

What causes the liquid crystal phase?

- **Thermotropic phase - liquid crystals arise from a change in temperature**
- **Lyotropic phase - phase arising from a change in concentration**

How are the particles arranged?

- **Nematic phase - molecules pointed in the same direction but ends not aligned (1-d order)**
- **Cholesteric - twisted nematic**
- **Smectic - aligned in rows and columns (2 -d order)**

Uses and examples

- **LCD displays - electric field causes changes in molecular orientation**
- **Cholesterol**
- **Cell membranes - nematic array of polar fatty molecules**
- **Voluntary muscle striations**