Chapter 2 - Chemical Bonds, Structures and Physical Properties

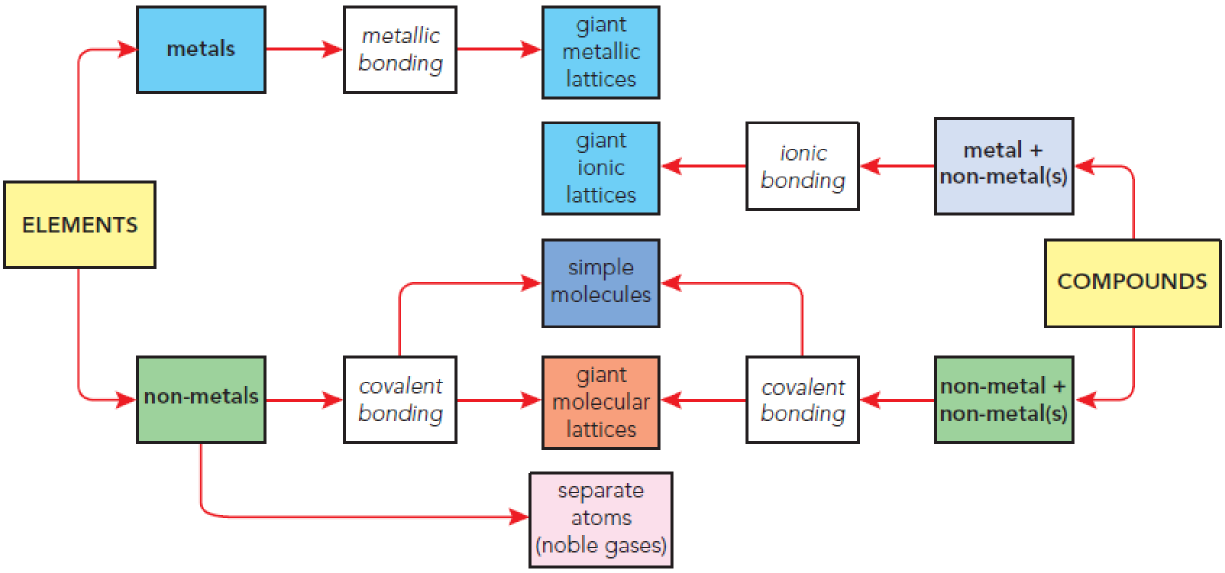
> Key points of the chapter:
>
> - Classification of Crystalline Solids
> - Chemical Bonds (and what defines it's strength)
> - Physical Properties of the Above
> - Lewis Structures
> - Shape of Molecules
> - Intermolecular forces
> - Comparison between Ionic Compounds and Covalent Compounds

Classification of Crystalline Solids

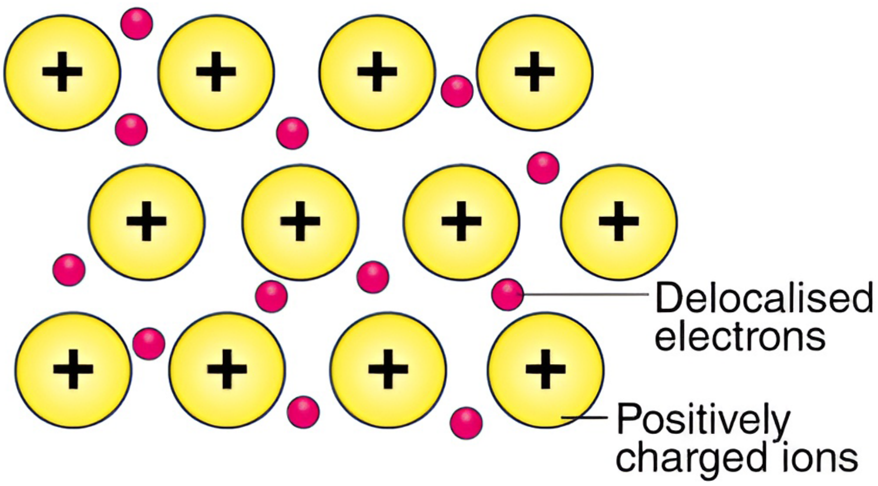
Classification of Crystalline Solids

	Metallic Solids	Ionic Solids	Covalent Network Solids / Giant Molecular Substances	Molecular Solids / Covalent Substances
Type of Attractions	Metallic bonds	Ionic Bonds	Intermolecular Forces	Covalent Bonds
Melting point	variable melting point, usually high	high to very high melting points	very high melting points	low melting points
Hardness and Brittleness	variable hardness	hard, brittle	very hard	variable hardness, variable brittleness
Conductivity	conducts heat and electricity well	conducts electricity under molten or aqueous state but not as a solid	usually not conductive	not conductive
Examples	Cu, Fe, Ti, Pb, U	NaCl, Al2O3, MgO	C (diamond), SiO2 (silica), SiC, graphite, C60	H2O, CO2, I2, C12H22O11

Chemical Bonds



Metallic Bonding



Metallic Bonding in Sodium

- *Metallic bond result from the **electrostatic attractive forces** between **positively charged metal** and mobile/**free electrons***
- The metallic bond is **stronger** when there're **more delocalized electrons**
  - The metallic bond of metals in group III is stronger than metals in group I
  - e.g. metallic bond of aluminum is stronger than the metallic bond of potassium

Physical Properties of Metallic Substances

1. **malleable** & **ductile**
   - Layer of atoms in a metal can slide over each other when a force is applied
   - Metals don't break as the *sea of electrons* holds the atoms together
2. conduct **electricity**
   - The **movement of delocalized electrons** through the metal lattice conducts electricity
   - Metals conduct electricity both when **solid** and when **molten**
3. conduct **heat**
   - When one end of the metal is heated, the delocalized electrons get more energy. They move faster and collide other electrons
   - **Heat is transferred in the collision**
4. have **high melting point and boiling point**
   - The metallic bonding in metals is strong, a lot of energy is needed to seperate the atoms

Alloys

Common Alloys	Composition
Steel 钢	C + Fe
Stainless Steel 不锈钢	Cr + Fe + NI
Bronze 青铜	Cu + Sn

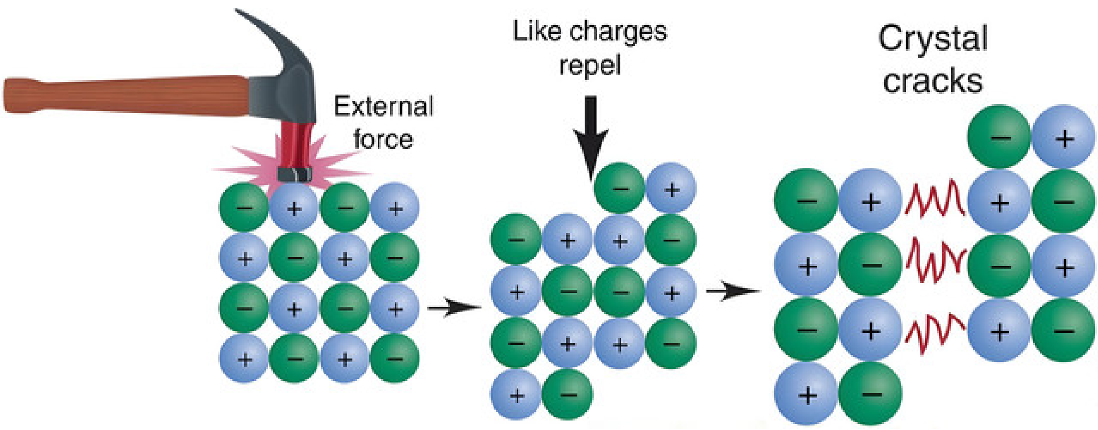
Common Alloys	Composition
Brass 黄铜	Cu + Zn

- Alloy is **not a compound** but a physical mixing of a metal plus at least one other material
- Many alloys are produced to give a **stronger metal**.
- The presence of the other atoms (smaller or bigger) disrupts the symmetry of the layers and reduces the ability of one layer to slide over another, results in a stronger, harder and less malleable metal.

Ionic Bonding

- Compounds formed between a **metal** and **non-metal** generally involve ionic bonding.
  - **Metal** atoms lose outer electrons to form positive ions (**cations**).
  - **Non-metal** atoms (except hydrogen) gain electrons to form negative ions (**anions**).
  - The **electrons** involved in the formation of ions are those in the **outer shell** of the atoms.
  - The ions formed a **more stable electronic configuration**, usually that of the **nearest noble gas** to them in the Periodic Table.
    - *Octet rule*: the tendency for atoms in compound to achieve noble gas configuration with eight valence electrons
- *Ionic bonds result from the **electrostatic attraction force between oppositely charged ions**.*
- We use **Lewis structure (dot and cross diagram)** to show the outer electrons that have taken part in the bonding

Physical Properties of Ionic Substances

1. have **high melting points and boiling points**
   - Ions are attracted to each other by strong electrostatic forces. Large amounts of energy are needed to overcome this attraction in order to allow the ions to move more freely and become molten
2. hard but brittle易碎的
   - 

   - Ionic solids are hard, rigid and brittle because of the strong electrostatic forces
   - Unlike metal, they're not malleable
   - Moving the ions requires overcoming strong ionic bonds, so ionic solids don't dent or bent
   - If the force is strong enough to break to attractions, ions of like charges are brought close together and their repulsion crack the crystal
3. **conduct electricity** when **molten** or **dissolved in water** (not when solid)

- In the liquid or solution, the ions are free to move about. They can move towards the electrodes when a voltage is applied.

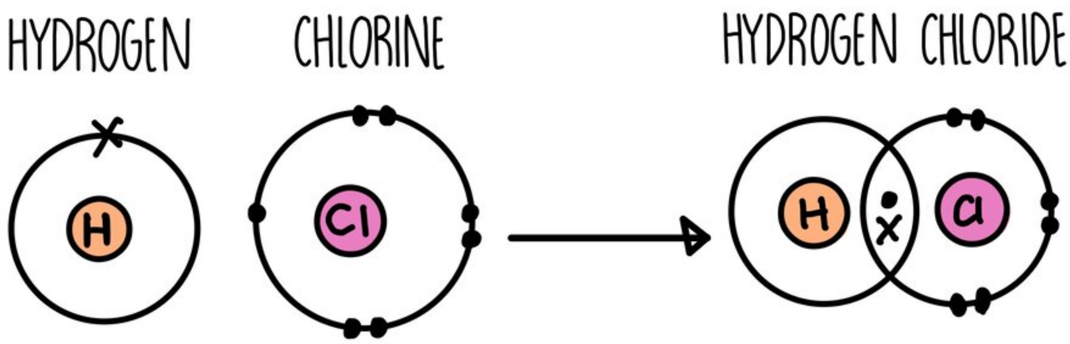
4. often **soluble in water** (not usually soluble in organic solvents)
    - Water (polar) is attracted to charged ions and therefore an ionic solids dissolve.

Lewis Structures

Practice: Lewis Structure of Ionic Compound

- NaCl, $MgCl_2$, K_2O, CaO, Al_2O_3, CaF_2, Na_2O, KF, MgF_2

Covalent Bonding



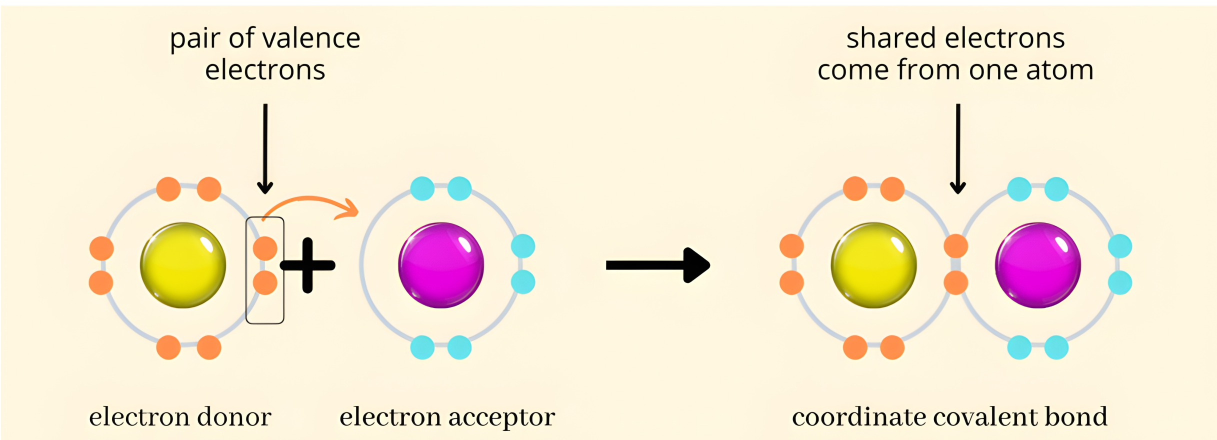
- Covalent bond: the electrostatic attraction force between the nuclei of adjacent atoms and share electron pairs
    - *electrostatic forces*: strong forces of attraction between particles with opposite charges

Lewis Structures

Practice: Lewis Structure of Covalent Compound

- H_2, Cl_2, HCl, H_2O

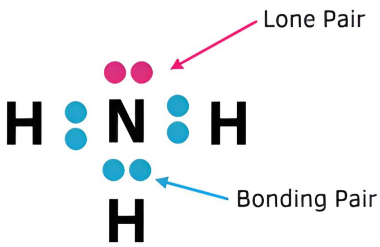
Coordinate Bond



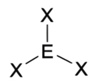
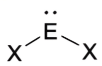
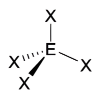
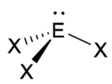
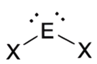
- Coordinate bond (a.k.a. dative bond) is a covalent bond in which **both electrons come from the same atom**
- Eg: SiO_2, CO, O_3

Shapes of Simple Molecules

- **VSEPR** (valence shell electron pair repulsion) **model** is used to **predict the shape of molecules** based on the repulsion between electron pairs in the valence shell of the atoms.
    - Because electrons repel each other electrostatically, the **most stable arrangement of electrons is the one that minimizes repulsions**
- There're two types of electron pairs



- Bonding pair (BP): A pair of electrons in a covalent bond
- Lone pair (LP): Electron pairs in the valence shell that are not involved in bonding
- Lone pair electron charge clouds repel more than bonding pair electron charge clouds.
    - LP - LP > LP - BP > BP - BP
- From the BP and LP interactions we can predict both the **relative positions of the atoms** and the angles between the bonds, called the **bonding angle**

Use VSEPR model to predict the geometry of molecules/ions					
	charged clouds	bonding pairs	lone pairs	Geometry	Examples
Linear	2	2	0	X—E—X Linear (EX_2)	CO_2, CS_2, $BeCl_2$, BeH_2, $HgBr_2$, HCN, COS, N_2O, BeF_2
Trigonal Planar	3	3	0	 Trigonal planar (EX_3)	BCl_3, BF_3, $AlCl_3$, SO_3, CO_3^{2-}
		2	1	 Bent (EX_2)	SO_2, SeO_2, O_3, $SnCl_2$
Tetrahedral	4	4	0	 Tetrahedral (EX_4)	CH_4, SiH_4, SnH_4, Cl_4, $SiCl_4$, $CHCl_3$, SO_4^{2-}
		3	1	 Trigonal pyramidal (EX_3)	NH_3, PH_3, AsH_3, SbH_3, PCl_3
		2	2	 Bent (EX_2)	H_2O, H_2S, H_2Se, H_2Te, F_2O, ClO_2^-

Practice: Lewis Structure & Geometry of Molecules/Ions

- CH_4, CCl_4, SO_2, H_2S, PCl_3, NH_3, CO_2, NCl_3, OF_2, SF_2, CS_2, Cl_2O, F_2, CH_3Cl, Cl_2O, NF_3, $SiCl_4$, SiO_2, **SO_3, CO, O_3**

Covalent Substances & Physical Properties

`对于simple molecular substances来说，组成molecules的atoms是covalently bonded的，但是molecule与molecule之间只有weak intermolecular forces, whereas giant molecular substances组成的基本单位为atoms，atoms之间是由强大的covalent bond连接的而不是intermolecular forces`

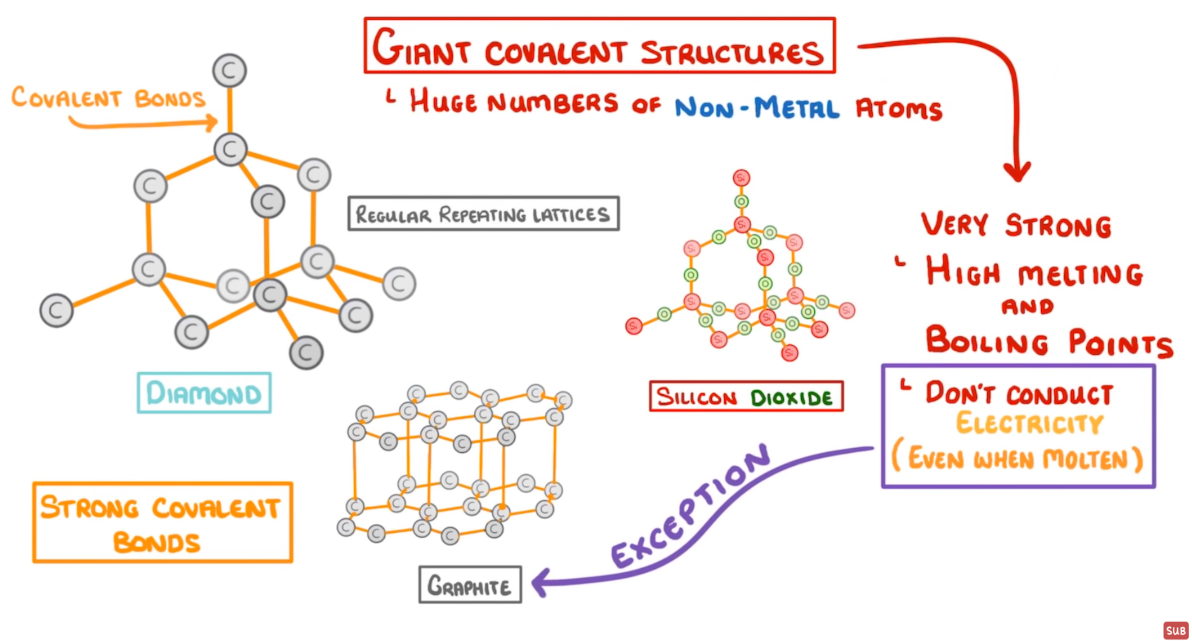
Simple Molecular Substances

- Simple molecular substances are small molecules that are made up of covalently bonded atoms. The simple molecules are only joined together by **weak intermolecular forces** (*Van der Waal's force*)

Physical Properties of Simple Molecular Substances

1. low melting point and boiling point
    - In order to melt or boil simple molecular substances, we actually don't break the covalent bonds between it. Instead we only need to break weak intermolecular forces
    - As the molecules get larger, the intermolecular forces would be bigger, more energy is required to break the intermolecular forces, so the m.p. and b.p. should increase as we go down the group
2. don't conduct electricity
    - no free electrons or ions
    - the molecules itself have no electric charges
3. solubility
    - soluble in non-aqueous solvent but are insoluble in water
4. soft and brittle
5. volatility
    - volatile and evaporate easily since they have low m.p. and b.p.

Giant Molecular Substances



- made of huge number of non-metal atoms that are bond to each other with **covalent bond**, arranged in regular repeating lattices, much stronger than simple molecular substances

Physical Properties of Giant Molecular Substances

1. high melting point and boiling point
    - strong covalent bonds need to be broken in order to melt them
2. generally don't conduct electricity
    - don't contain any charged paricles
    - except graphite

Comparisons Between Ionic Compounds and Covalent Compounds

Comparisons Between Ionic Compounds and Covalent Compounds

	Ionic Compounds	Covalent Compounds (Simple Molecule)	Covalent Compounds (Giant Molecule)
M.p. and B.p.	High	Low	High
Volatility	Non-volatile	Very volatile	Non-volatile
Solubility	Soluble in water; insoluble in non-aqueous solvent	Insoluble in water; soluble in non-aqueous solvent	Insoluble in both water and non-aqueous solvent
Electrical Conductivity	Conduct electricity in molten and aqueous solution	Does not conduct electricity in any state	Does not conduct electricity in any state