Comparison of Properties of Ionic, Covalent, and Metallic Compounds

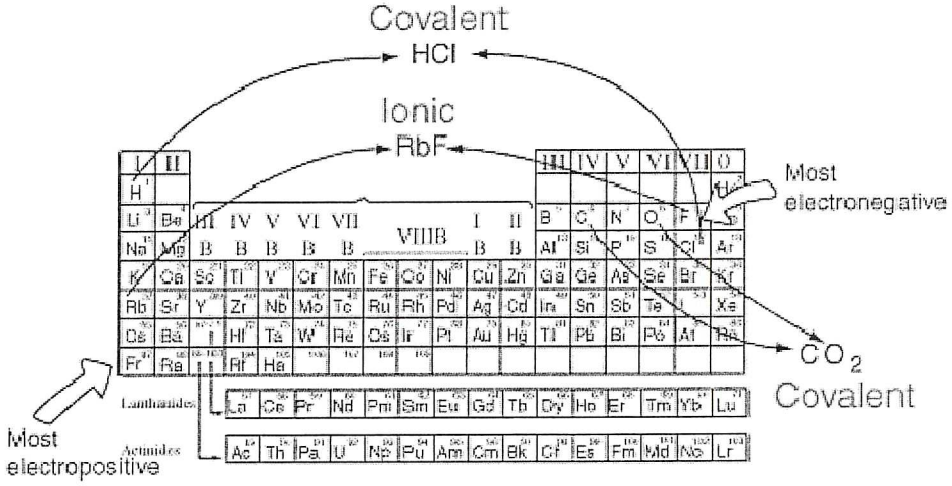
Because of the nature of ionic, covalent, and metallic bonds, the materials produced by those bonds tend to have quite different macroscopic properties.

Ionic Compounds

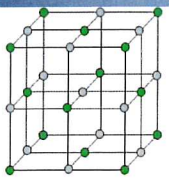
1. Crystalline solids (made of ions) – ions have very strong forces of attraction for each other – forces extend throughout crystal structure
2. High melting (NaCl m pt. = 800°C)
3. Conduct electricity when melted and when dissolved in water (nonconductors as solids)
4. Many soluble in water but not in nonpolar liquids
5. Brittle
6. Hard solids

Covalent Compounds

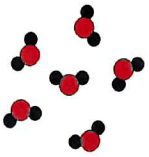
1. Gases, liquids, or solids (made of molecules)
2. Low melting (CCl_4 m pt. = -23.0°C) and boiling points
3. Poor electrical conductors in all phases (Nonconductors when dissolved in water)
4. Many are soluble in nonpolar liquids but not in water
5. Atoms are held strongly to each other within molecules, but molecules do not have strong forces of attraction for each other
6. Brittle
7. "Soft" solids



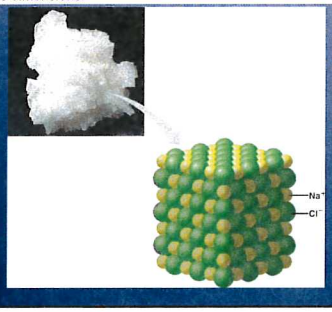
Ionic Solids



An ionic compound has alternating positively and negatively charged particles in a pattern that extends in all three dimensions.



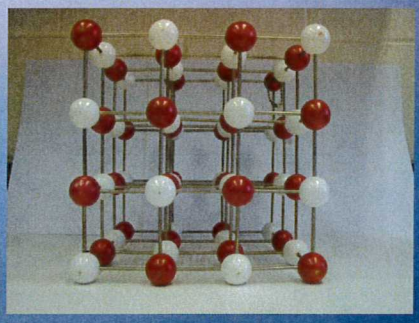
A molecular compound has discrete groups of atoms joined together to form molecules.

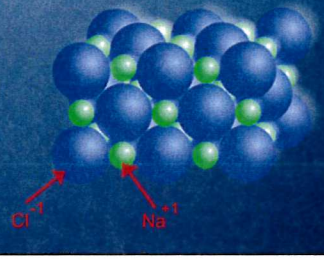


- Ionic solids are solids composed of ionic particles (ions).
- These ions are held together in a regular array by *ionic bonding*.
- Ionic bonding results from attractive interactions from oppositely charged ions.
- In a typical ionic solid, positively charged ions are surrounded by negatively charged ions and vice-versa.
- The close distance between these oppositely charged particles results in very strong attractive forces.
- The alternating pattern of positive and negative ions continues in three dimensions.
- The regular repeating pattern is analogous to the tiles on a floor or bricks on a wall.
- called the crystal lattice.

Ionic Compounds

- Crystalline solids (made of ions)
- High melting and boiling points
- Conduct electricity when melted or dissolved in water
  - Demo: Electrolytes
- Many are soluble in water but not in non-polar liquid





Characteristics of Chemical Bonded Compounds

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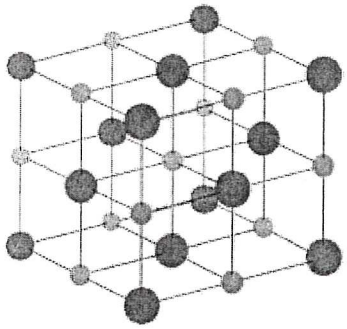
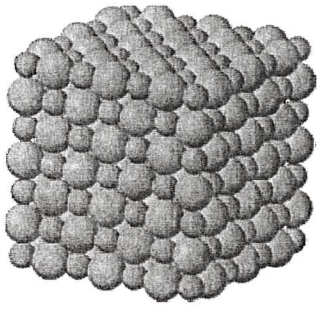


Crystal lattice of NaCl (small spheres = Na+, large spheres = Cl-)



NaCl Lattice

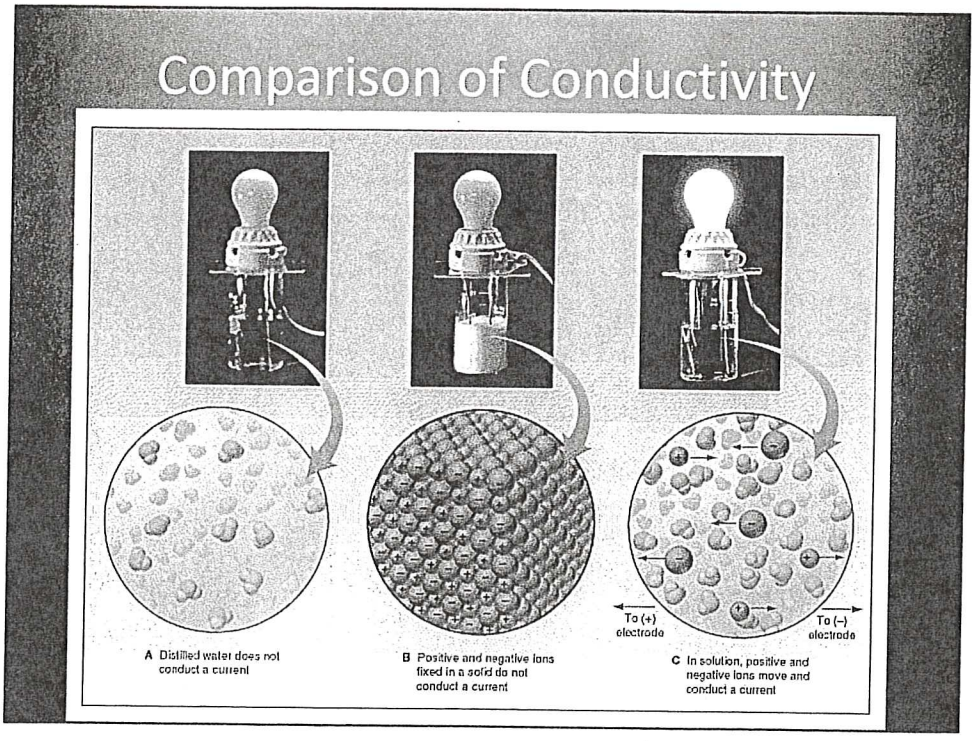
- **All ionic compounds form crystals.** So far as is known, there are no exceptions to ionic compounds existing as crystalline solids at room temperature. The smallest "piece" of a crystal that reflects the same shape as the overall crystal is called the "unit cell". There are ten or so different general shapes of unit cells.

- **Ionic compounds tend to have high melting and boiling points.** Most of the time, when you work with ionic compounds in a chemistry class, the melting point is hot enough that the solids cannot be melted with a Bunsen burner. Why are these melting temperatures so high? The answer is the way that ionic materials are held together. Ionic crystals are basically big blocks of positive and negative charges all stuck together. To break the positive and negative charges apart, it takes a huge amount of energy. This means that if we heat up the compound to add energy, it takes a huge amount of energy to break it apart.

- **Ionic compounds are very hard and very brittle.** Again, this is because of the way that they're held together. Above, we said that it takes a lot of energy to

break the positive and negative charges apart from each other. This is the reason that ionic compounds are so hard - they simply don't want to move around much, so they don't bend at all. This also explains the brittleness of ionic compounds. It takes a lot of energy to pull ionic charges apart from each other. However, if we give a big crystal a strong enough whack with a hammer, we usually end up using so much energy to break the crystal that the crystal doesn't break in just one spot, but in a whole bunch of places. Instead of a clean break, it shatters.

- **Ionic compounds conduct electricity when they dissolve in water.**



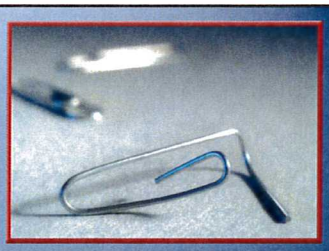
Metals and Metallic Bonding

- Typical Properties of Metals
  - Malleable
  - Ductile
  - Good Conductors of Heat and Electricity
  - Generally high melting and boiling points

Metallic Bonds

- The properties of metals suggest that their atoms possess strong bonds
- yet the ease of conduction of heat and electricity suggest that electrons can move freely in all directions in a metal
- The general observations give rise to a picture of "positive ions in a sea of electrons" to describe metallic bonding.

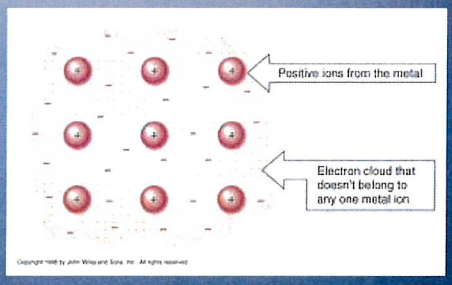
Metal Properties



- Malleable and Ductile
- Strong and Durable
- Good conductors of heat and electricity.
- Their strength indicates that the atoms are difficult to separate… strong bonds
- but malleability and ductility suggest that the atoms are relatively easy to move in various directions.
- The electrical conductivity suggests that it is easy to move electrons in any direction in these materials.
- The thermal conductivity also involves the motion of electrons. All of these properties suggest the nature of the metallic bonds between atoms. (Electron sea model)

Metallic Bonding
Electron Sea Model

- Explained by the Electron Sea Model
- the atoms in a metallic solid contribute their valence electrons to form a "sea" of electrons that surrounds metallic cations.
- delocalized electrons are not held by any specific atom and can move easily throughout the solid.
- A metallic bond is the attraction between these electrons and the metallic cation.



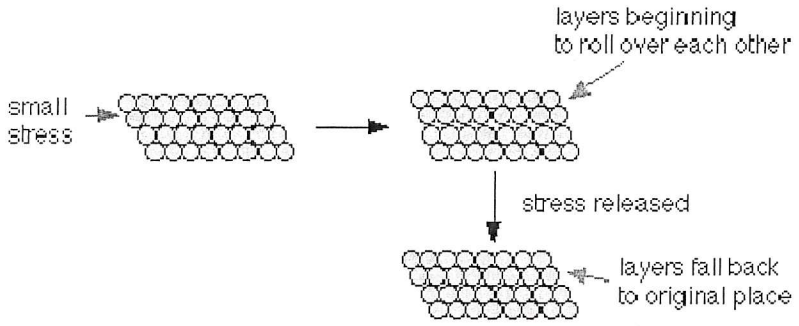
Metallic Compounds

1. Solids
2. Malleable
3. Ductile
4. Range of melting points
5. Excellent electrical conductors in all phases

Malleability and ductility

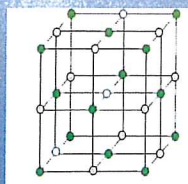
Metals are described as ***malleable*** (can be beaten into sheets) and ***ductile*** (can be pulled out into wires). This is because of the ability of the atoms to roll over each other into new positions without breaking the metallic bond.

If a small stress is put onto the metal, the layers of atoms will start to roll over each other. If the stress is released again, they will fall back to their original positions. Under these circumstances, the metal is said to be ***elastic.***



Covalent (Molecular) Compounds

- Gases, liquids, or solids (made of molecules)
- Low melting and boiling points
- Poor electrical conductors in all phases
- Many soluble in non-polar liquids but not in water



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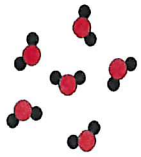

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Ionic Compounds	**Covalent Compounds**	**Metallic Compounds**
-Formed from a combination of metals and nonmetals. -Electron transfer from the cation to the anion. -Opposite charged ions attract each other.	-Formed from a combination of nonmetals. -Electron sharing between atoms.	-Formed from a combination of metals -"sea of electrons"; electrons can move among atoms
Solids at room temperature	Can be solid, liquid, or gas at room temperature.	Solids at room temperature
High melting points	Low melting points	Various melting points
Dissolve well in water	Do not dissolve in water (Sugar is an exception)	Do not dissolve in water.
Conduct electricity only when dissolved in water; electrolytes	Do not conduct electricity; non electrolytes	Conduct electricity in solid form.
Brittle, hard	Soft	Metallic compounds range in hardness. Group 1 and 2 metals are soft; transition metals are hard. Metals are malleable, ductile, and have luster.

COMPARISON OF CHEMICAL BOND TYPES

	Ionic	*Covalent*	*Metallic*
What is the basic composition?			
What is the goal of bond formation?			
What role do the electrons play?			
What is the force responsible for bonding?			
What results (name) from the bond formation?			
What are the general properties of the compounds that result from each type of bonding?			

CHPT 6 CHEMICAL BONDING
PROPERTIES OF BONDED MATERIALS

TYPE OF BOND	GENERAL PROPERTIES	**WHY?** *(what about the way the elements are bonded explains the properties)*
IONIC		
COVALENT		
METALLIC		

Ionic Compounds	Covalent Compounds	Metallic Compounds
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