BONDING Notes

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Introduction to Bonding

- Atoms are generally found in nature in combination held together by chemical bonds.
- A chemical bond is a mutual electrical attraction between the nuclei and valence electrons of different atoms that binds the atoms together.
- There are three main types of bonding: ionic, metallic and covalent.

Introduction to Bonding

- Ionic Bonding occurs between a metal and a nonmetal.
- Metallic bonding occurs between two metals .
- Covalent bonding occurs between a nonmetal and a nonmetal.
- A positive ion is called a cation.
- A negative ion is called an anion.

Introduction to Bonding

What determines the type of bond that forms?

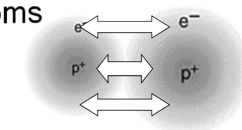
- The valence electrons of the two atoms involved are redistributed to the most stable arrangement.
- The interaction and rearrangement of the valence electrons determines which type of bond that forms.
  - Before bonding the atoms are at their highest possible potential energy

Introduction to Bonding

- There are 2 philosophies of atom to atom interaction
  - One understanding of the formation of a chemical bond deals with balancing the opposing forces of repulsion and attraction
  - Repulsion occurs between the negative e^- clouds of each atom
  - Attraction occurs between the positive nuclei and the negative electron clouds

Introduction to Bonding

- When two atoms approach each other closely enough for their electron clouds to begin to overlap
  - The electrons of one atom begin to repel the electrons of the other atom
  - And repulsion occurs between the nuclei of the two atoms



Introduction to Bonding

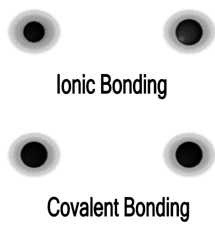
- As the optimum distance is achieved that balances these forces, there is a release of potential energy
  - The atoms vibrate within the window of maximum attraction/minimum repulsion
- The more energy released the stronger the connecting bond between the atoms

Introduction to Bonding

- Another understanding of the form-ation of a chemical bond between two atoms centers on achieving the most stable arrangement of the atoms' valence electrons
  - By rearranging the electrons so that each atom achieves a noble gas-like arrangement of its electrons creates a pair of stable atoms (only occurs when bonded)

Introduction to Bonding

- Sometimes to establish this arrange-ment one or more valence electrons are transferred between two atoms
  - Basis for ionic bonding
- Sometimes valence electrons are shared between two atoms
  - Basis for covalent bonding



Introduction to Bonding

- A good predictor for which type of bonding will develop between a set of atoms is the difference in their electro-negativities.
  - Remember, electro-negativity is a measure of the attraction an atom has for e⁻s after developing a bond
- The more extreme the difference between the two atoms, the less equal the exchange of electrons

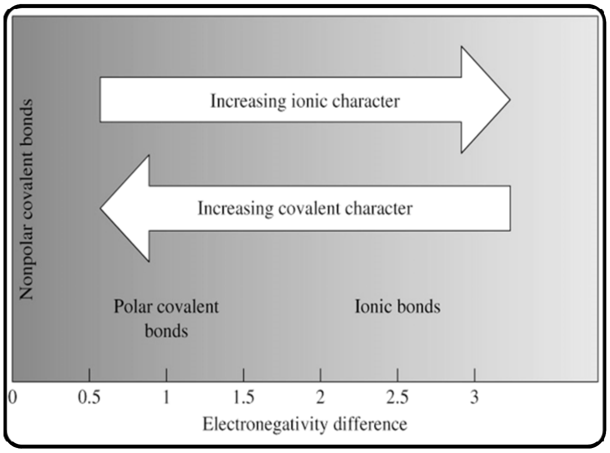
below 1.0; 1.0–1.4; 1.5–1.9; 2.0–2.4; 2.5–2.9; 3.0–4.0

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
H 2.1																
Li 1.0	Be 1.5											B 2.0	C 2.5	N 3.0	O 3.5	F 4.0
Na 0.9	Mg 1.2											Al 1.5	Si 1.8	P 2.1	S 2.5	Cl 3.0
K 0.8	Ca 1.0	Sc 1.3	Ti 1.5	V 1.6	Cr 1.6	Mn 1.5	Fe 1.8	Co 1.8	Ni 1.8	Cu 1.9	Zn 1.6	Ga 1.6	Ge 1.8	As 2.0	Se 2.4	Br 2.8
Rb 0.8	Sr 1.0	Y 1.2	Zr 1.4	Nb 1.6	Mo 1.8	Tc 1.9	Ru 2.2	Rh 2.2	Pd 2.2	Ag 1.9	Cd 1.7	In 1.7	Sn 1.8	Sb 1.9	Te 2.1	I 2.5
Cs 0.8	Ba 0.9	La* 1.1	Hf 1.3	Ta 1.5	W 2.4	Re 1.9	Os 2.2	Ir 2.2	Pt 2.2	Au 2.4	Hg 1.9	Tl 1.8	Pb 1.8	Bi 1.9	Po 2.0	At 2.2
Fr 0.7	Ra 0.9	Ac† 1.1														

*Lanthanides: 1.1–1.3
†Actinides: 1.3–1.5

Introduction to Bonding

- Let's consider the compound Cesium Fluoride, CsF.
  - The electro-negativity value (EV) for Cs is .70; the EV for F is 4.00.
    - The difference between the two is 3.30, which falls within the scale of ionic character.
- When the electro-negativity difference between two atoms is greater than 1.5 the bond is **mostly** ionic.



Introduction to Bonding

- The take home lesson on electro-negativity and bonding is this:
  - The closer together the atoms are on the P.T., the more evenly their e^- interact, and are therefore more likely to form a covalent bond
  - The farther apart they are on the P.T., the less evenly their e^- interact, and are therefore more likely to form an ionic bond.

metal w/nonmetal = ionic
nonmetal w/nonmetal = covalent

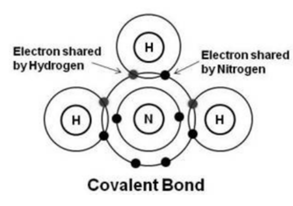
Ionic Bonds

- Forming ionic bonds can be represented as **a transfer of electrons.**

$Na\cdot \quad \cdot\ddot{\underset{\cdot\cdot}{Cl}}\!: $ to give $Na^+ \; :\ddot{\underset{\cdot\cdot}{Cl}}:^-$

Simply as $Na^+ Cl^-$
or NaCl

Covalent Bonding



Covalent Bonding

- In a <u>covalent</u> bond:
  - The electro-negativity difference between the atoms involved is not extreme
    - So the interaction between the involved electrons is more like a sharing relationship
  - It may not be an equal sharing relationship, but at least the electrons are being "shared".

Covalent Bonding

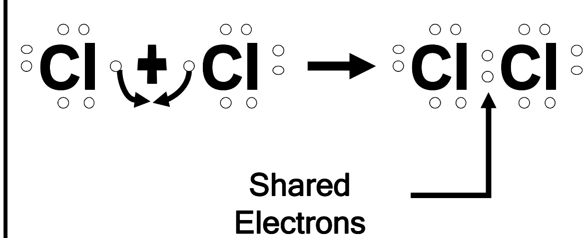
- Covalent Bonding is between two or more non-metals.
- Covalent bonds are formed when electrons are shared between two atoms.
- If they share 2 electrons, they form a single bond; 4 electrons is a double bond;
- If two atoms share 6 electrons, they form a triple bond.

Covalent Bonding

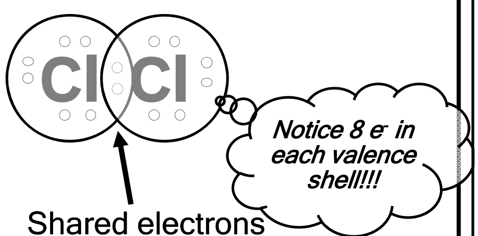
- Polar bonds usually involve nitrogen, oxygen or fluorine (NOF)
- Non-Polar bonds usually involve carbon-hydrogen bonds
- In polar bonds, the electrons are shared unequally
- In non-polar bonds, the electrons are shared equally.
- Covalent compounds can exist in any state (solid, liquid or gas). They have low melting and boiling points.

Covalent Bonds

Lets look at the molecule Cl_2



each atom must have 8 valence e's

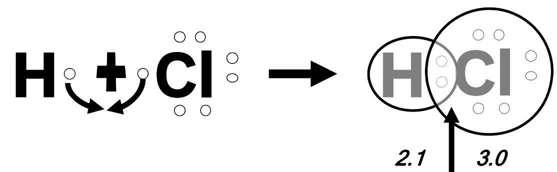


Shared electrons are counted with both atoms

Cl_2

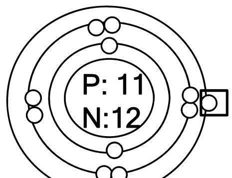
Covalent Bonds

How about the molecule HCl?

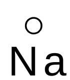


(Polar Covalent)
shared, but not evenly

Bohr and Lewis Diagrams



Bohr model of Sodium Atom



Lewis Structure of Sodium Atom

Lewis Structures

- A <u>**Lewis structure**</u> is a diagram showing the arrangement of only the valence electrons of the atoms in a molecule.
- We use <u>dots</u> to represent valence electrons involved in bonding.
- <u>Valence electrons</u> are electrons present in the outermost energy level of an atom.

Valence electrons for Elements

Recall that the valence electrons for the elements can be determined based on the elements position on the periodic table.

Examples of Lewis Dot Symbol

IA	IIA	IIIA	IVA	VA	VIA	VIIA	VIIIA
H ·							
Li ·	·Be·	·B·	·C·	:N·	:O·	:F·	:Ne:
Na·	·Mg·	·Al·	·Si·	:P·	:S·	:Cl·	:Ar:
K ·	·Ca·						

Bonds

- Atoms can share more than one electron pair.
- They may double or triple up pairs of electrons to satisfy the octet rule.
- A Single bond is the sharing of one pair of electrons between two atoms.
- A Double bond is the sharing of two pairs of electrons between two atoms.
- A Triple bond is the sharing of three pairs of electrons between two atoms.

Valence electrons and number of bonds

Number of bonds element can form depends on the number of valence electrons.

In general -

Family		→	# Covalent Bonds*
Halogens F, Br, Cl, I	X	→	1 bond often
Calcogens O, S	O	→	2 bond often
Nitrogen N, P	N	→	3 bond often
Carbon C, Si	C	→	4 bond always

The above chart is a guide on the number of bonds formed by these atoms.

Bonds

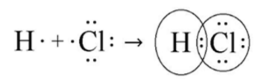
4 bonds	3 bonds	2 bonds	1 bond
:O=C=O:	:N≡N:	:O = O:	:F – F:

Rules for Writing Lewis Structures

1. Determine whether the compound is <u>covalent or ionic</u>. If covalent, treat the entire molecule. If ionic, treat each ion separately.
2. Determine the <u>total</u> number of <u>valence electrons</u> available to the molecule or ion by summing the valence electrons of all the atoms in the unit.
3. Organize the atoms so there is a <u>central atom</u> (usually the least electronegative) surrounded by ligand (outer) atoms. Hydrogen is never the central atom.

Bonds

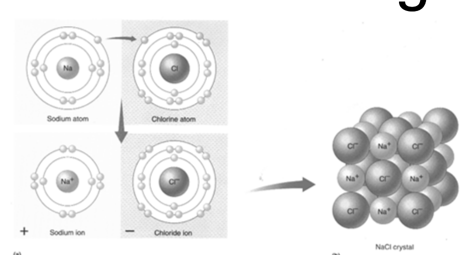
- So forming covalent bonds can be shown as



<u>So what's the bottom line?</u>

To be stable the two atoms involved in the covalent bond share their electrons in order to achieve the arrangement of a <u>noble gas</u>.

Ionic Bonding



Ionic Bonding

- In an Ionic bond:
  - The electro-negativity difference is extreme,
    - So the atom with the stronger pull doesn't really share the electron
  - Instead the electron is essentially transferred from the atom with the least attraction to the atom with the most attraction

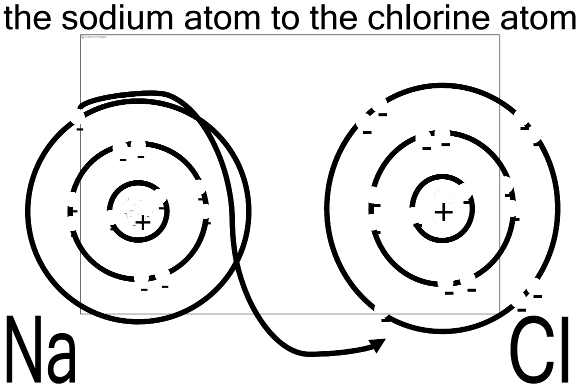
Ionic Bonding

- *When a metal bonds with a nonmetal an:* ***Ionic bond*** *is formed*
- **An ionic bond contains a positive and negative ion.**
- **-A positive ion is called a cation.**
- **-A negative ion is called an anion.**
- **-An Ionic bonding always involves the transfer of an electron from the metal to the nonmetal.**
- **-The cation and anion are held together by electrostatic attraction.**

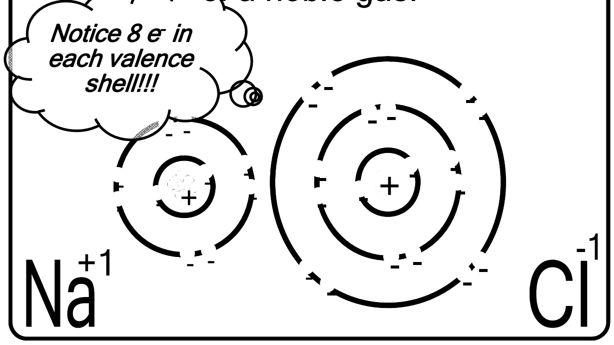
Characteristics of Ionic Compounds

- Ionic compounds do not consist of individual molecules. Instead there is a huge network of positive and negative ions that are packed together in a solid brittle crystal lattice.
- Because their bonds are strong, ionic compounds tend to have very **high melting and boiling points**
- -Ionic compounds are electrolytes, which means they can conduct electricity
- When forming ionic compounds the positive and negative charges must balance
- **Ionic crystals cannot conduct electricity because the ions must be able to move.**

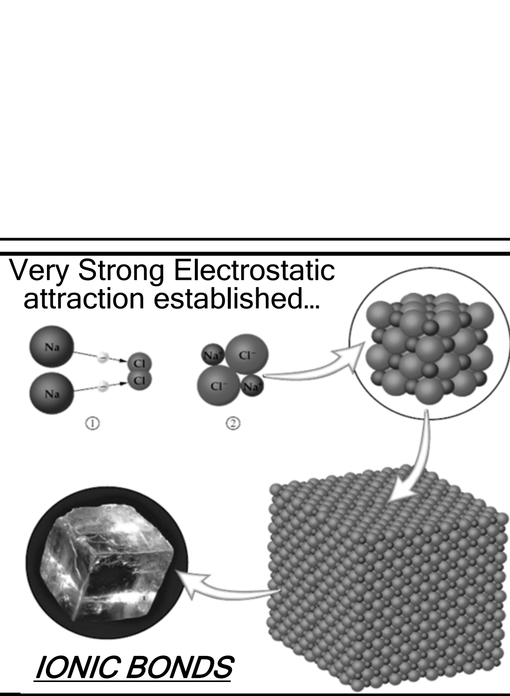
An electron is transferred from the sodium atom to the chlorine atom



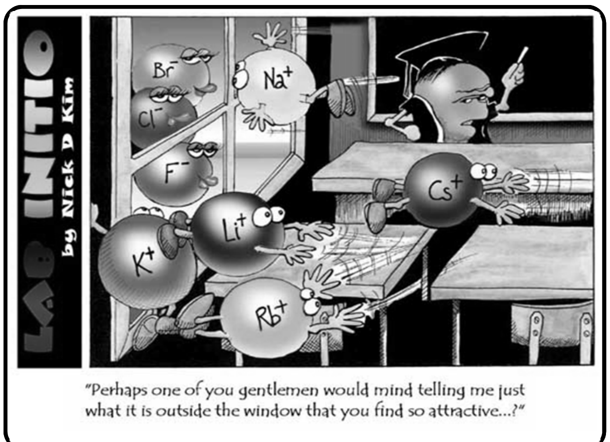
Both atoms are happy, they both achieve the electron arrangement of a noble gas.



Very Strong Electrostatic attraction established…



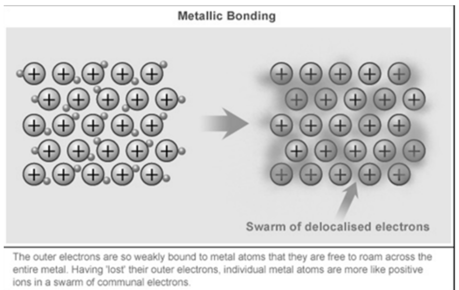
IONIC BONDS



So what's the bottom line?

To be stable the two atoms involved in the ionic bond will either lose or gain their valence electrons in order to achieve a stable octet arrangement of electrons.

Metallic Bonding



Metallic Bonding

- **The metallic bond consists of positively charged metallic cations that donate electrons to the sea.**
- **The sea of electrons are shared by all atoms and can move throughout the structure.**

Metallic Bonding

Properties of metals

Thermal conductivity

Electrical conductivity

Malleability - The ability of a material to be hammered into thin sheets.

Ductility - The ability of a material to be drawn into a wire.

Metallic Bonding

- In a metallic bond:
  - The resulting bond is a cross between covalent and ionic bonding
    - Valence electrons are transferred from one metal atom to the surrounding metal atoms
    - But none of the involved metal atoms want the electrons from the original atom, nor their own so they pass them on

Introduction to Metallic Bonding

- What results is a sharing/transfer of valence electrons that none of the atoms in the collection own the valence electrons
  - It resembles a collection of positive ions floating around in a sea of electrons