# Basic Concepts of Chemical Bonding

## 8.1 Chemical Bonds, Lewis Symbols, & the Octet Rule

## 8.2 Ionic Bonding (+7.3 ionic radius trends)

## 8.3 Covalent Bonding

## 8.4 Bond Polarity & Electronegativity



# Types of Chemical Bonds

**Ionic Bond:**

**Due to electrostatic forces between opposite charges (metal + nonmetal)**

**Covalent Bond:**

**Sharing of electrons between two atoms (nonmetal + nonmetal)**

**Metallic Bond:**

**In metals where each atom bonded to several atoms and bonding electrons move freely around them**



# Valence Electrons

**The outer shell (valence shell) electrons of an atom**

**The electrons that participate in chemical bonding**

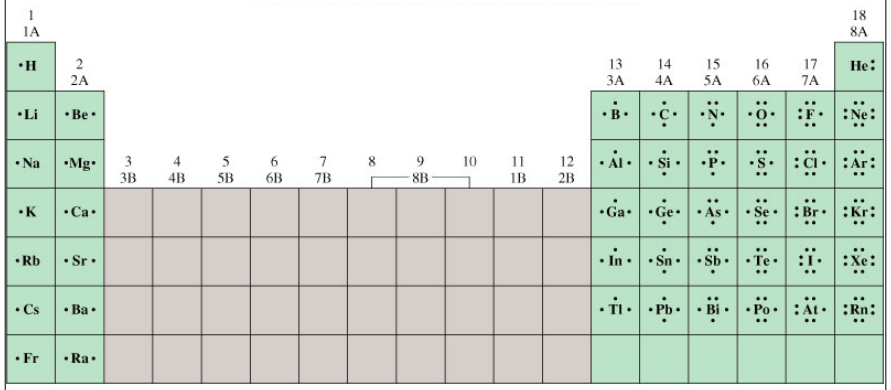


# Valence Electrons

| Group | $e^-$ configuration | # of valence $e^-$ |
|---|---|---|
| 1A | $ns^1$ | 1 |
| 2A | $ns^2$ | 2 |
| 3A | $ns^2\ np^1$ | 3 |
| 4A | $ns^2\ np^2$ | 4 |
| 5A | $ns^2\ np^3$ | 5 |
| 6A | $ns^2\ np^4$ | 6 |
| 7A | $ns^2\ np^5$ | 7 |

## Lewis Symbols

**Chemical symbol for the element plus a dot for each valence electron.**






## Octet Rule:

**Atoms tend to gain, lose, or share electrons until they are surrounded by eight valence electrons (noble gas configuration)**

| | | |
|---|---|---|
| Na: [Ne] $3s^1$ | $Na^+$: [Ne] | lose |
| Cl: [Ne] $3s^2\ 3p^5$ | $Cl^-$: [Ne] $3s^2\ 3p^6$ | gain |
| $Cl_2$: [Ne] $3s^2\ 3p^5$ |  | Share |



## Ionic Bond

$Na(s) + \frac{1}{2}\ Cl_2(g) \rightarrow NaCl(s)$

Na $1s^2\ 2s^2\ 2p^6\ 3s^1$

 $\rightarrow Na^+ + e^-$

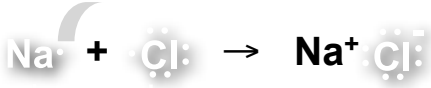
Cl $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^5$

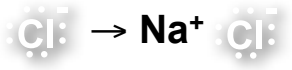
 $+ e^- \rightarrow Cl^- \rightarrow$ 

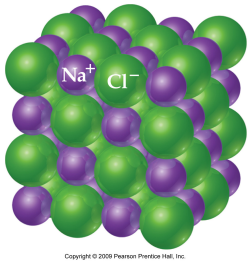


## Ionic Bond

$Na(s) + \frac{1}{2}\ Cl_2(g) \rightarrow NaCl(s)$

 $\rightarrow Na^+$ 

$Na^+ +$  $\rightarrow Na^+$ 




**Ionic Bond: Electrostatic attraction between cations (positively charged ions) and anions (negatively charged ions)**

## How Strong is the Ionic Bond?

**Strength measured by the lattice energy of the ionic compound.**

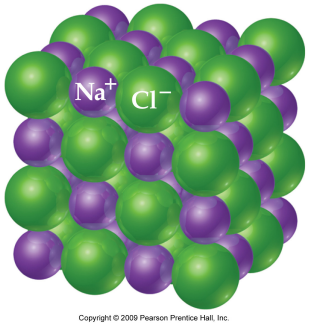
**Lattice Energy ($E_l$):**

**Energy required to completely separate one mole of a solid ionic compound into gaseous ions.**

$$NaCl(s) \rightarrow Na^+(g) + Cl^-(g)$$



## Crystal Structure of NaCl





**Each $Na^+$ is surrounded by 6 $Cl^-$**

**Each $Cl^-$ is surrounded by 6 $Na^+$**



| Compound | $E_l$ (kJ/mol) |
|---|---|
| LiF | 1012 |
| $MgCl_2$ | 2527 |
| MgO | 3890 |
| ScN | 7547 |

$$E = \frac{kQ_1Q_2}{d}$$

**Lattice energy increases with increasing ionic charge and with decreasing ionic size.**

**Charge effect more than size.**



## Atomic Radius

# Ionic Radius

## Follow the same trend as atomic radius

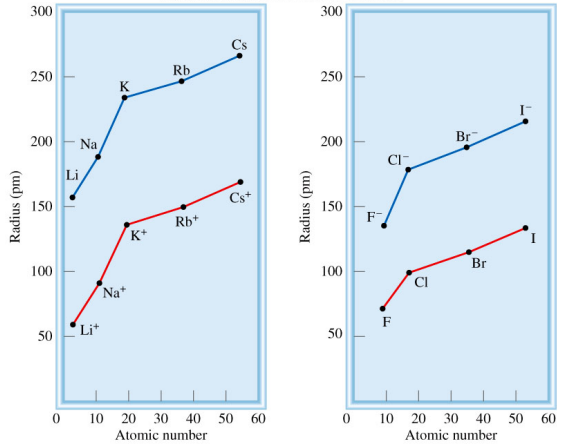





**TABLE 9.1** Lattice Energies and Melting Points of Some Alkali Metal and Alkaline Earth Metal Halides and Oxides

| Compound | Lattice Energy (kJ/mol) | Melting Point (°C) |
|---|---|---|
| LiF | 1017 | 845 |
| LiCl | 828 | 610 |
| LiBr | 787 | 550 |
| LiI | 732 | 450 |
| NaCl | 788 | 801 |
| NaBr | 736 | 750 |
| NaI | 686 | 662 |
| KCl | 699 | 772 |
| KBr | 689 | 735 |
| KI | 632 | 680 |
| $MgCl_2$ | 2527 | 714 |
| $Na_2O$ | 2570 | Sub* |
| MgO | 3890 | 2800 |

*$Na_2O$ sublimes at 1275°C.



## Arrange in order of increasing lattice energy

**LiF, LiI, and LiCl**

**LiI < LiCl < LiF**

**$MgF_2$, $ScF_3$, and LiF**

**LiF < $MgF_2$ < $ScF_3$**

**MgO, SrO and CaO**

**SrO < CaO < MgO**

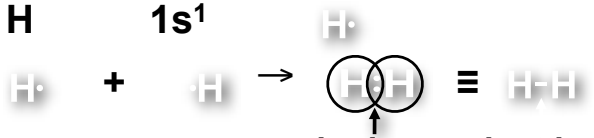


# Covalent Bond

**Forms when two atoms in a molecule share a pair of e-, one e- from each atom.**

**$H_2$ molecule:**

**H 1s1**

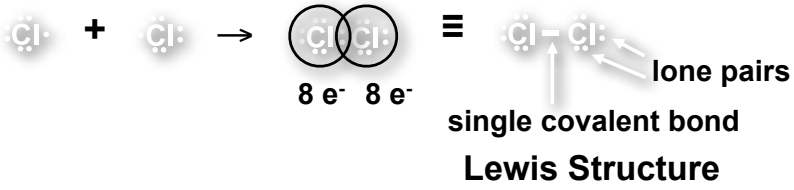



**single covalent bond**

**Lewis Structure**

**Every covalent bond is made from 2 electrons shared by both atoms.**

## $Cl_2$ molecule:




Lewis Structure

## HCl molecule:

Lewis Structure



## $H_2O$ molecule:

## $NF_3$ molecule:



# Multiple Bonds

## $CO_2$ molecule:


## $N_2$ molecule:




**Bond Strength:**

| N≡N | N=N | N-N | |
|---|---|---|---|
| 941 | 418 | 163 | kJ/mol |

triple > double > single

**Bond Length**

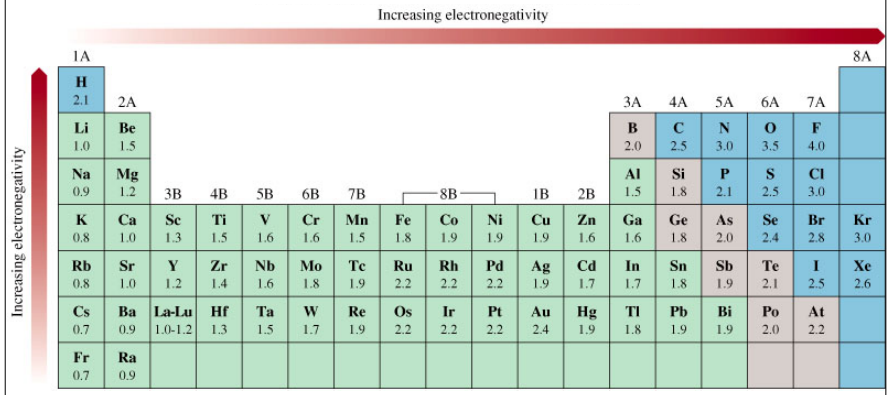
| N≡N | N=N | N-N | |
|---|---|---|---|
| 1.10 | 1.24 | 1.47 | Å |

triple < double < single

**As the number of shared e⁻ between the two atoms increases bond strength increases and length decreases.**

# Electronegativity

**Ability of an atom <u>in a molecule</u> to attract bonded electrons to itself.**






# Bond Polarity & Electronegativity

H:H  :Cl:Cl:

**In $H_2$ and $Cl_2$ molecules electrons of the covalent bond are shared equally by the two atoms**

**Result: Nonpolar (pure) covalent bond**



**In HCl molecule, electrons are not equally shared between H and Cl atoms due difference in electronegativity**

**Electrons spend more time closer to Cl because it has higher electronegativity than H atom.**

δ+ δ-

H :Cl:

**Bond has a dipole (two poles)**

**dipole moment $\mu = Qr$**


**Result: Polar covalent bond**



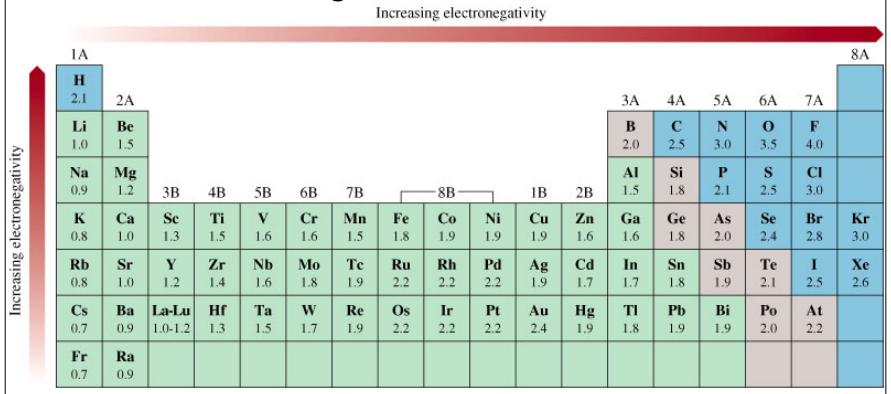
## Covlaent/polar covalent/or ionic

**Parameter:**

**Difference in electronegativity, ΔEN**

| | | |
|---|---|---|
| **ΔEN ≥ 2** | **ionic bond** | **NaCl** |
| **ΔEN < 2** | **polar covalent bond** | **CO** |
| **ΔEN = 0** | **pure covalent bond** | **$F_2$** |

## The Electronegativities of Common Elements




Increasing difference in electronegativity

Covalent Share e$^-$ → Polar Covalent partial transfer of e$^-$ → Ionic transfer e$^-$



## Which is the most polar bond?

**S – Cl, S – Br, Se – Cl, Se – Br**

**Se – Cl**