Chapter 4
Octet Rule and Ions

Octet Rule

An **octet**

- means **8 valence electrons**.
- is associated with the stability of the noble gases.

Exception:

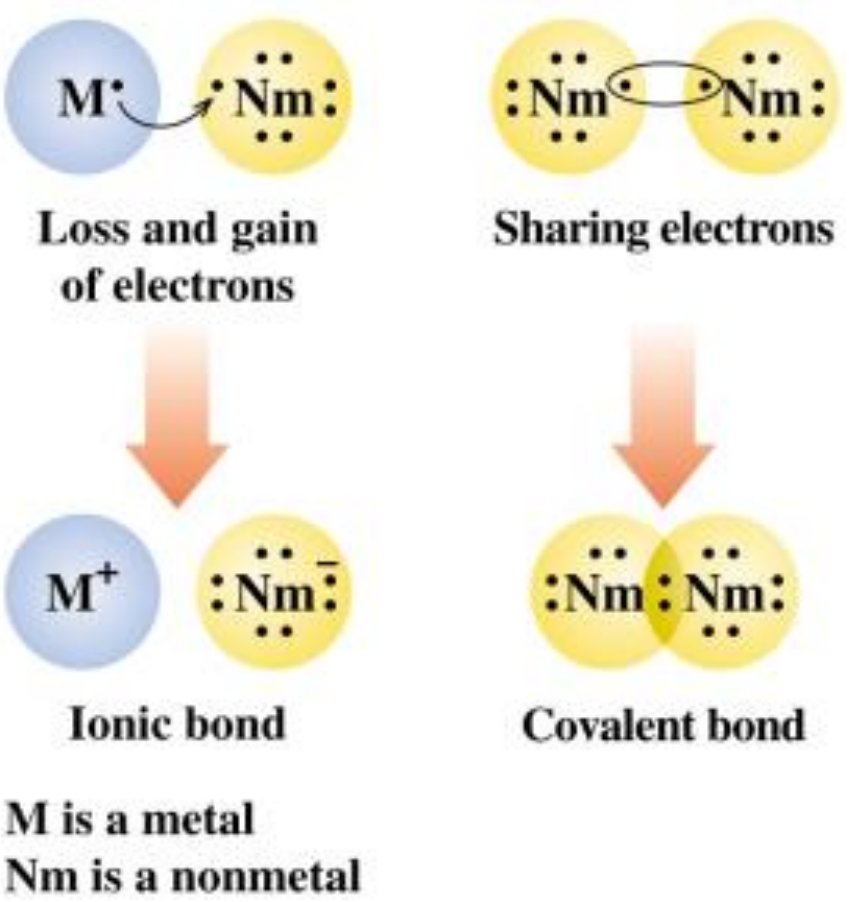
Helium (He) is stable with 2 valence electrons.

	Electron level arrangement	**valence electrons**
He	**2**	**2**
Ne	2, **8**	**8**
Ar	2, 8, **8**	**8**
Kr	2, 8, 18, **8**	**8**

Ionic and Covalent Bonds

Atoms form **octets**

- to become more stable.
- by **losing, gaining, or sharing** valence electrons.
- by forming ionic bonds or covalent bonds.



Metals Form Positive Ions

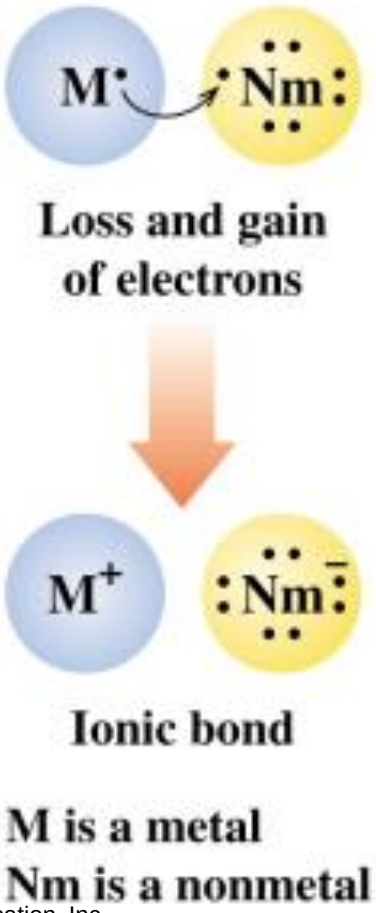
Metals form positive ions

- by a loss of their valence electrons.
- with the electron configuration of the nearest noble gas.
- that have fewer electrons than protons.

Group 1A metals $\longrightarrow$ ion $^{1+}$

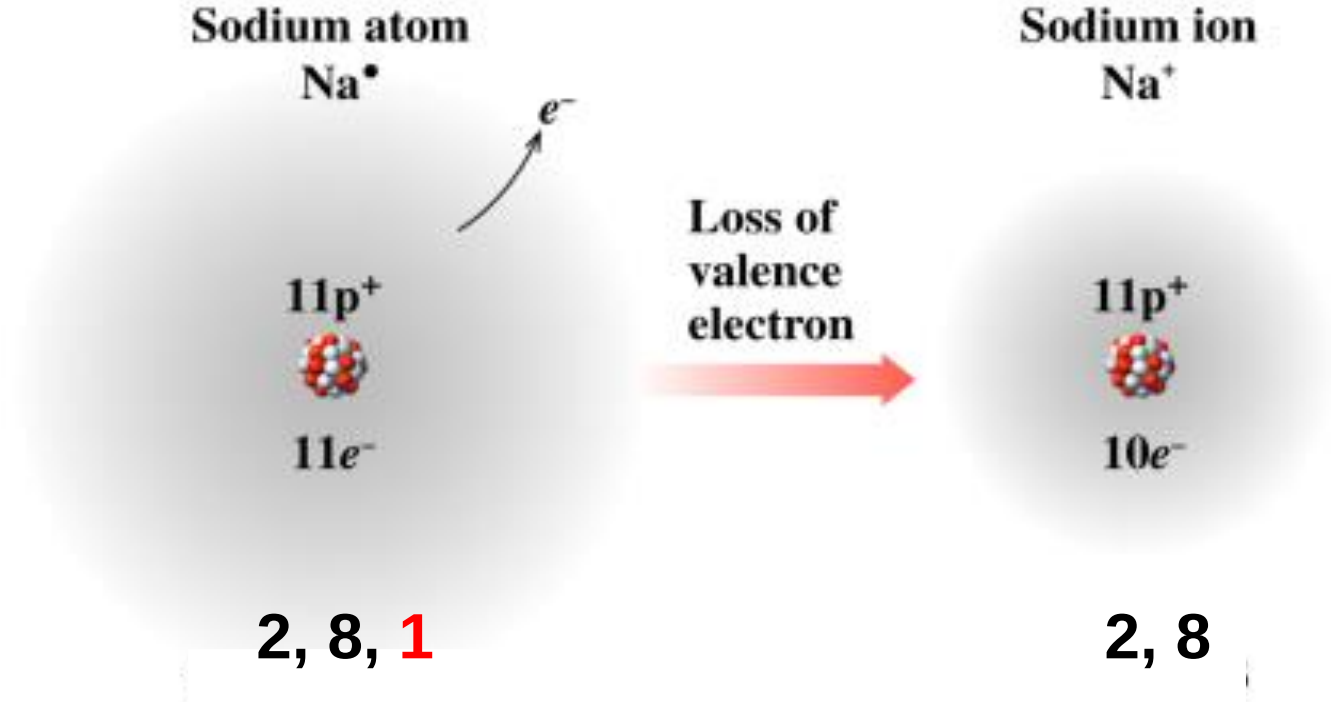
Group 2A metals $\longrightarrow$ ion $^{2+}$

Group 3A metals $\longrightarrow$ ion $^{3+}$



Formation of a Sodium Ion, Na^+

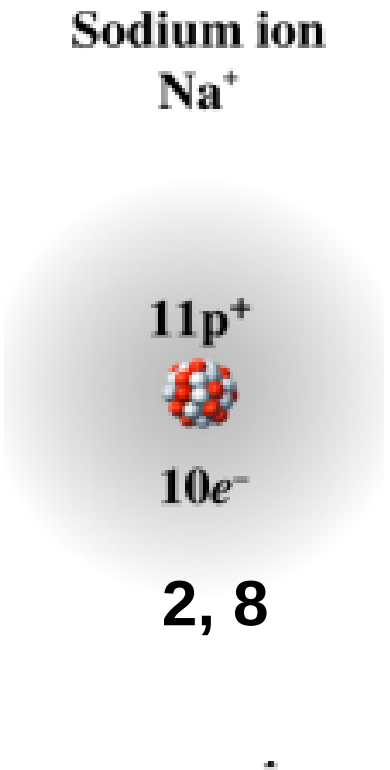
Sodium achieves an octet by losing its one valence electron.



Charge of Sodium Ion, Na^+

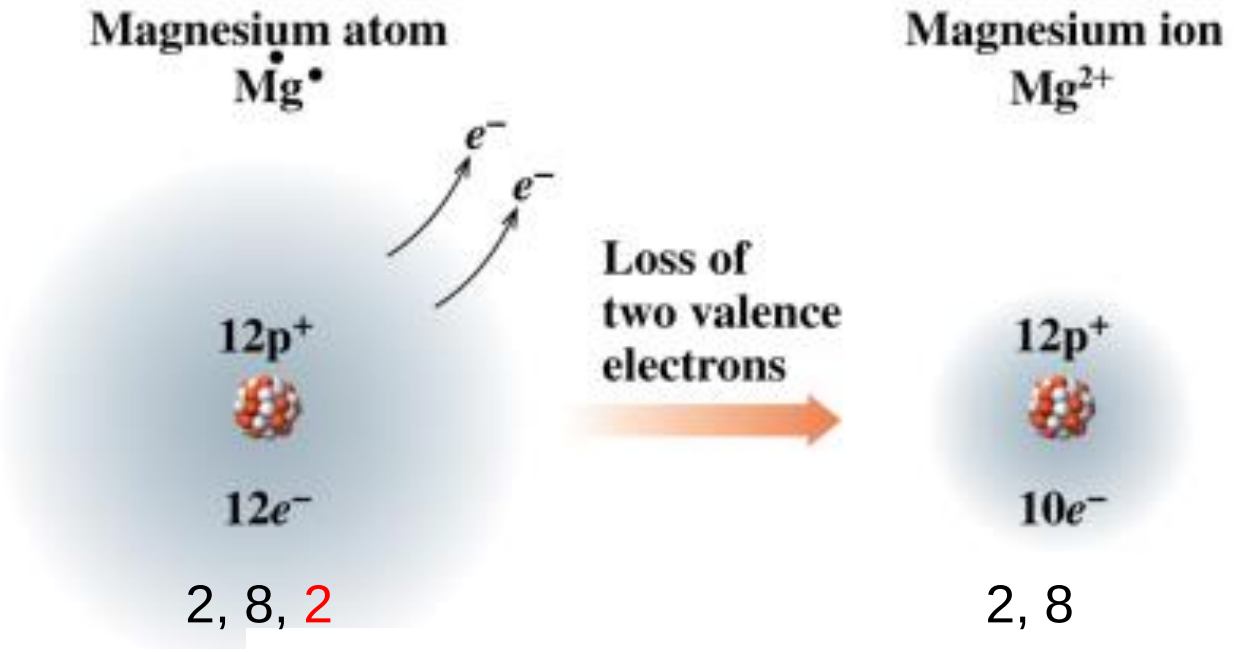
With the loss of its valence electron, the sodium ion has a +1 charge.

Sodium atom	Sodium ion
$11p^+$	$11p^+$
$11e^-$	$10e^-$
0	1+



Formation of Mg^{2+}

Magnesium achieves an octet by losing its two valence electrons.



Learning Check

A. The number of valence electrons in aluminum is

1) $1e^-$. 2) $2e^-$. 3) $3e^-$.

B. The change in electrons for octet requires a

1) loss of $3e^-$. 2) gain of $3e^-$. 3) a gain of $5e^-$.

C. The ionic charge of aluminum is

1) 3-. 2) 5-. 3) 3+.

D. The symbol for the aluminum ion is

1) Al^{3+}. 2) Al^{3-}. 3) Al^{+}.

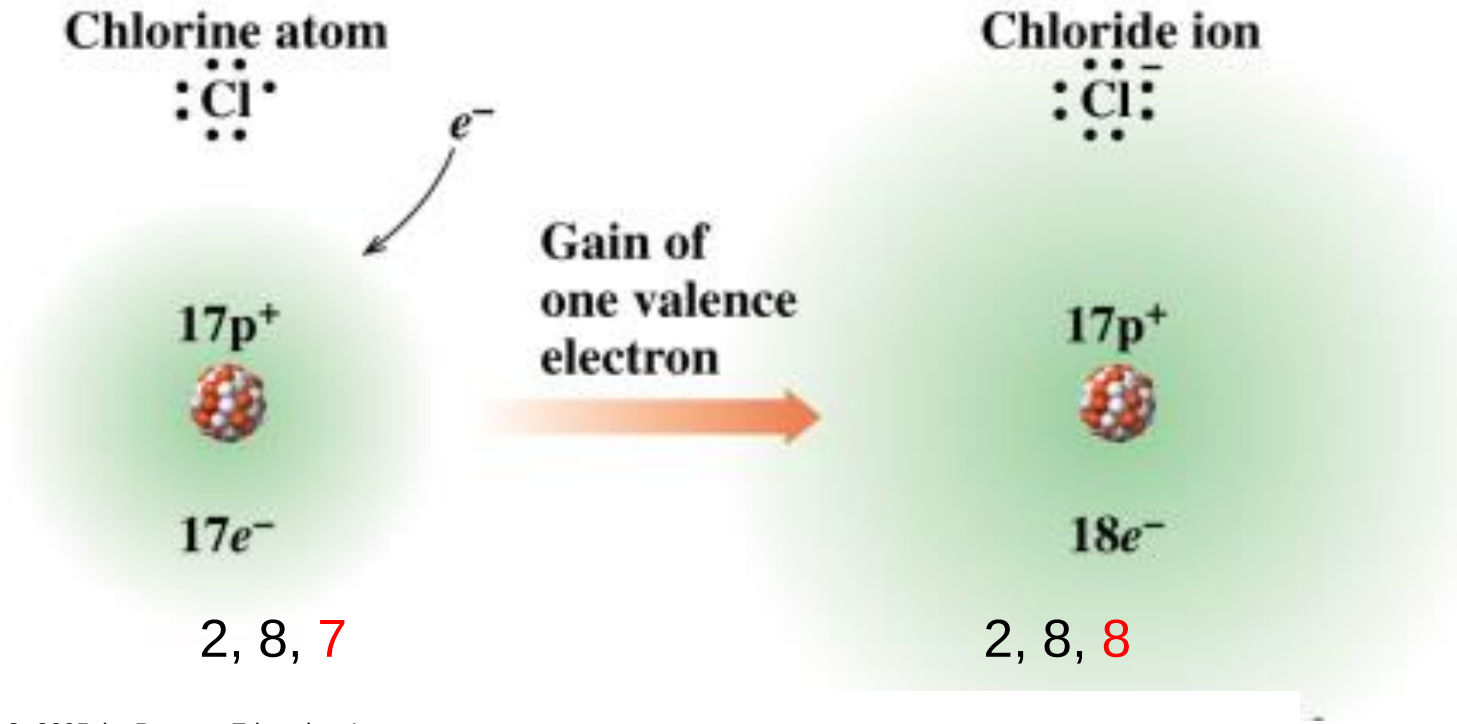
Formation of Negative Ions

In ionic compounds, **nonmetals**

- achieve an octet arrangement.
- **gain electrons**.
- form negatively charged ions with 3-, 2-, or 1- charges.

Formation of a Chloride, Cl^-

Chlorine achieves an octet by adding an electron to its valence electrons.



Charge of a Chloride Ion, Cl^-

By gaining one electron, the chloride ion has a -1 charge.

Chlorine atom		**Chloride ion**
$17p^+$		$17p^+$
$\underline{17e^-}$	$\xrightarrow{+\ 1\ e^-}$	$\underline{18e^-}$
0		1^-

Some Ionic Charges

Group Number	Number of Valence Electrons	Electron Change to Give an Octet	Ionic Charge	Examples
Metals				
1A (1)	1	Lose 1	1+	Li^+, Na^+, K^+
2A (2)	2	Lose 2	2+	Mg^{2+}, Ca^{2+}
3A (13)	3	Lose 3	3+	Al^{3+}
Nonmetals				
5A (15)	5	Gain 3	3−	N^{3-}, P^{3-}
6A (16)	6	Gain 2	2−	O^{2-}, S^{2-}
7A (17)	7	Gain 1	1−	F^-, Cl^-, Br^-, I^-

Ionic Compounds

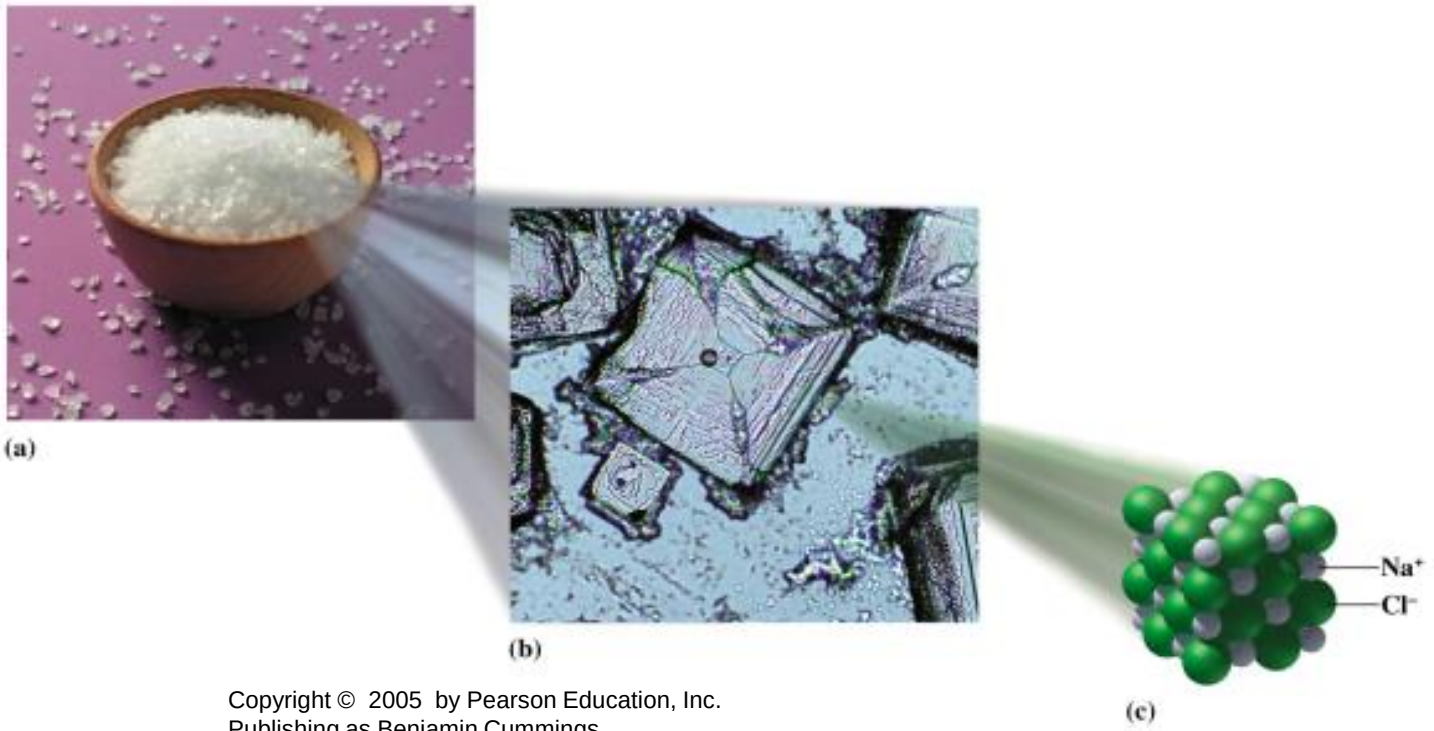
Ionic Compounds

Ionic compounds

- consist of positive and negative ions.
- have attractions called **ionic bonds** between positively and negatively charged ions.
- have high melting and boiling points.
- are solid at room temperature.

Salt is An Ionic Compound

Sodium chloride or “table salt” is an example of an ionic compound.



Ionic Formulas

An **ionic formula**

- consists of positively and negatively charged ions.
- is neutral.
- has charge balance.

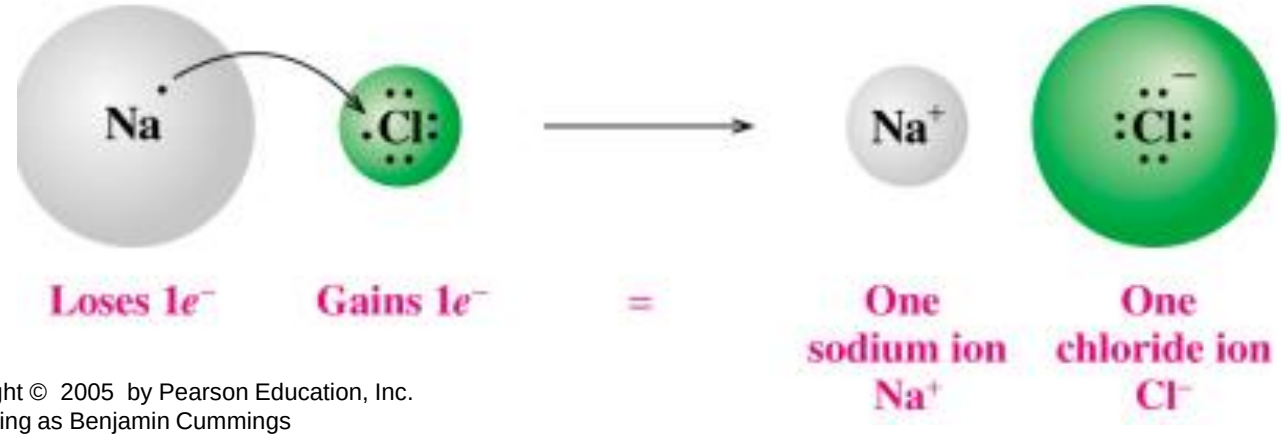
  total positive charge = total negative charge

  The symbol of the metal is written first followed by the symbol of the nonmetal, e.g. NaCl.

Charge Balance for NaCl, “Salt”

In NaCl,

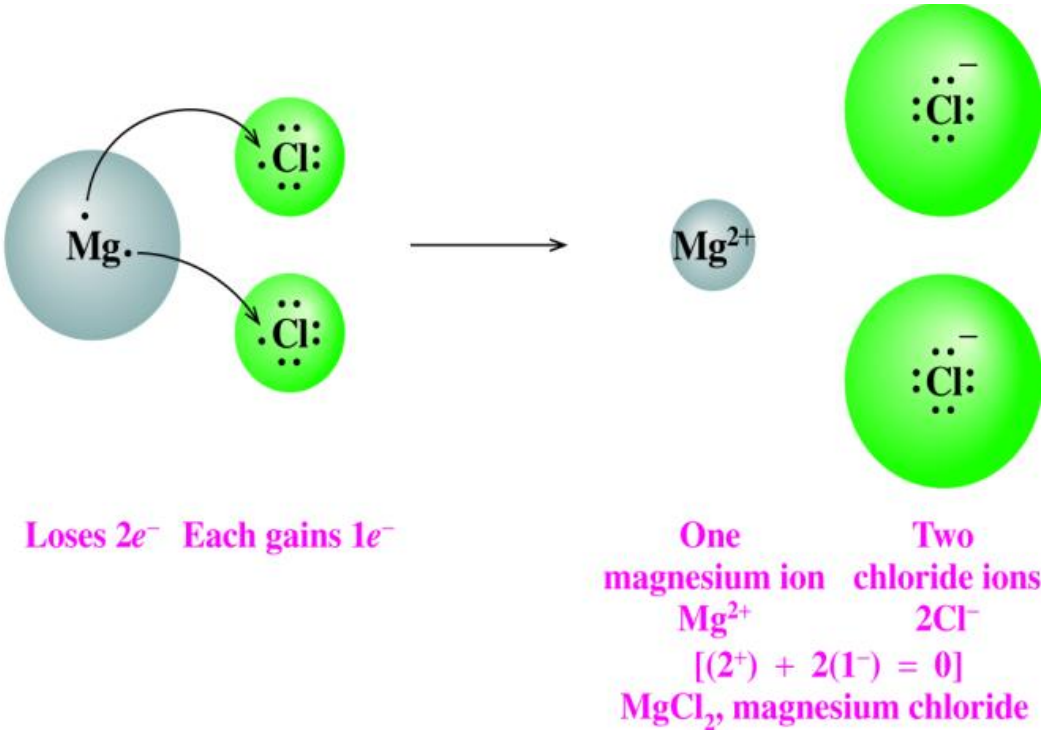
- a Na atom loses its valence electron.
- a Cl atom gains an electron.
- the symbol of the metal is written first followed by the symbol of the nonmetal.



Charge Balance In $MgCl_2$

In $MgCl_2$,

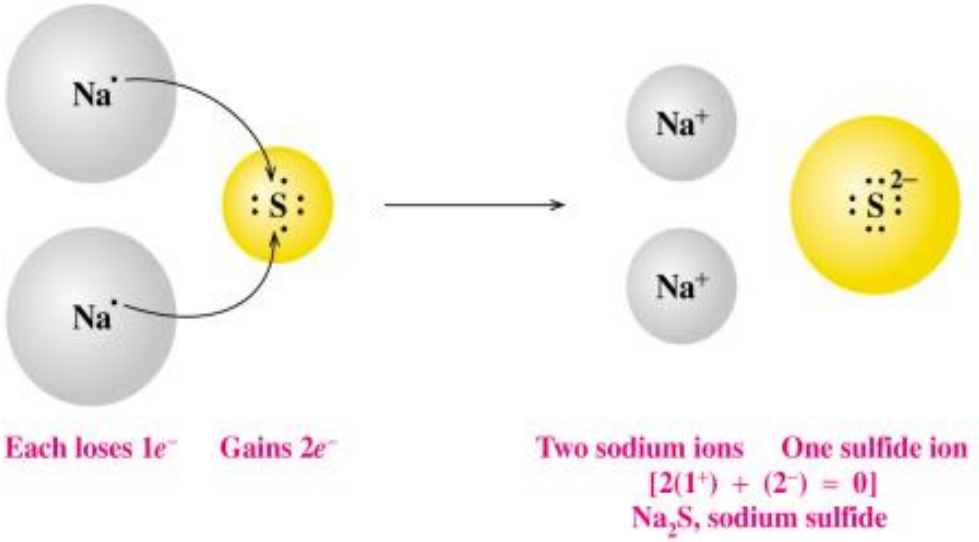
- a Mg atom loses two valence electrons.
- two Cl atoms each gain one electron.
- subscripts indicate the number of ions needed to give charge balance.



Charge Balance in Na_2S

In Na_2S.

- two Na atoms lose one valence electron each.
- one S atom gains two electrons.
- subscripts show the number of ions needed to give charge balance.



Formula from Ionic Charges

Write the ionic formula of the compound with Ba^{2+} and Cl^{-}.

- Write the symbols of the ions.

  Ba^{2+} Cl^{-}

- Balance the charges.

  Ba^{2+} Cl^{-} *two* Cl^{-} *needed*
  Cl^{-}

- Write the ionic formula using a **subscript 2** for two chloride ions that give charge balance.

  $BaCl_2$

Lets try it out!

Select the correct formula for each of the following ionic compounds.

A. Na^{+} and S^{2-}

1) NaS 2) Na_2S 3) NaS_2

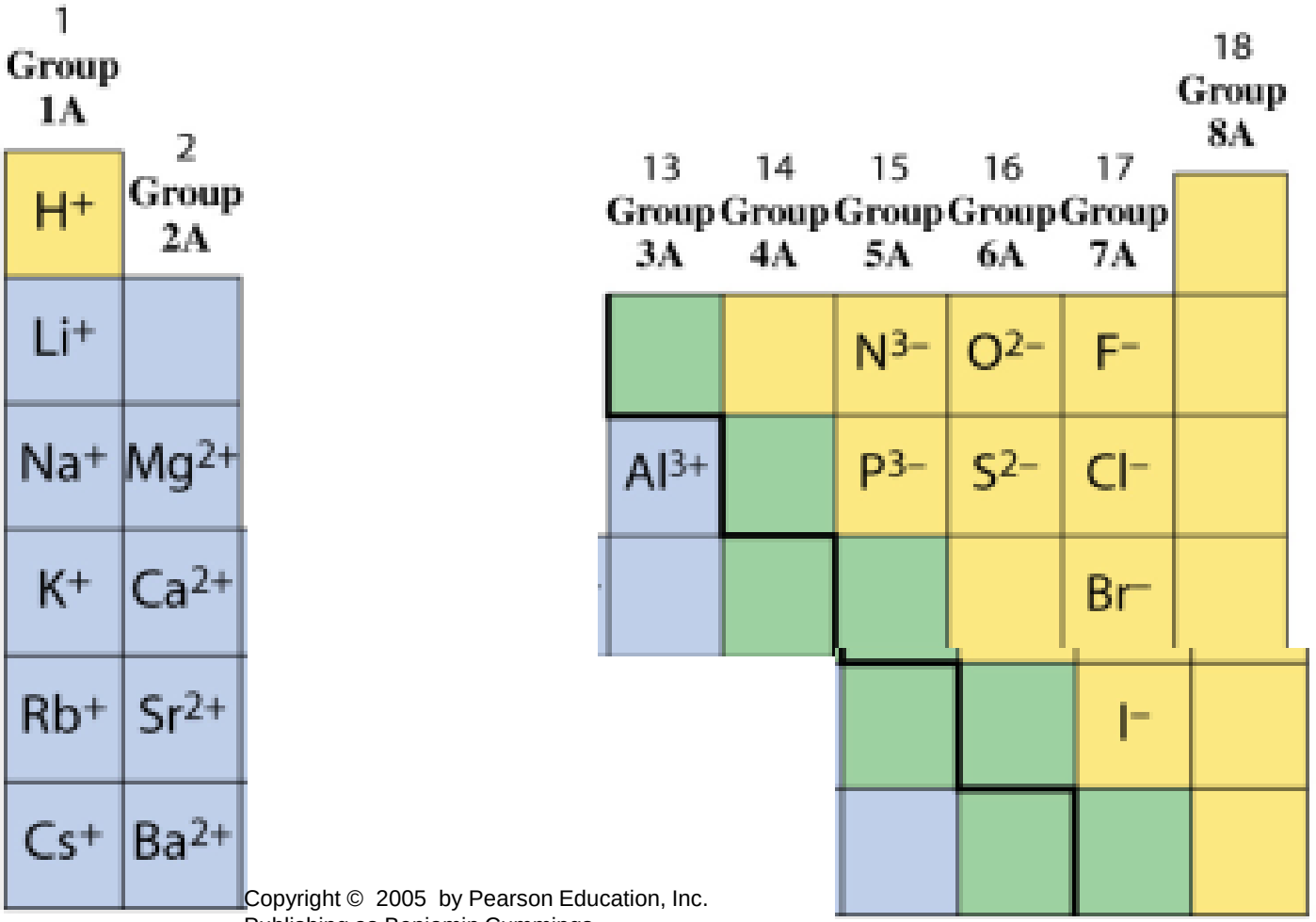
B. Al^{3+} and Cl^{-}

1) $AlCl_3$ 2) AlCl 3) Al_3Cl

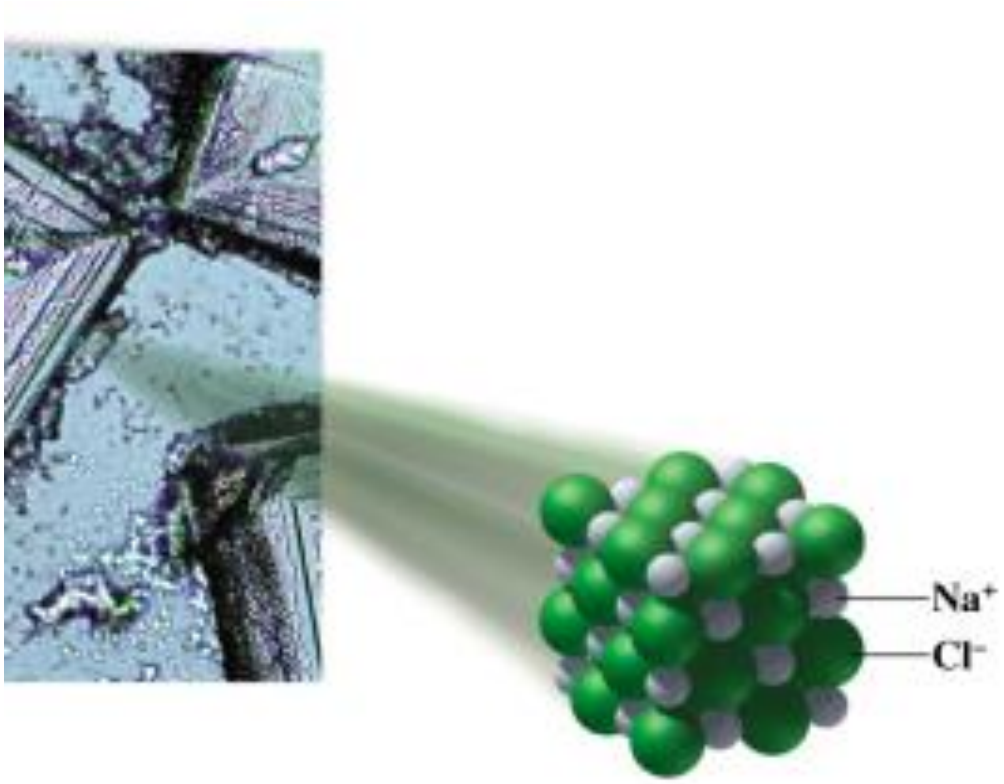
C. Mg^{2+} and N^{3-}

1) MgN 2) Mg_2N_3 3) Mg_3N_2

Charges of Representative Elements



Naming and Writing Ionic Formulas



An Ion is a charged particle

- A cation is positively charged
- (the giver, the metal)

- An Anion is the negatively charged particle
- (The taker or the nonmetal)

Naming Ionic Compounds with Two Elements

To name a compound that contains two elements,

- identify the **cation** and **anion**.
- name the cation first followed by the name of the anion.

Examples of Ionic Compounds with Two Elements

Formula	Ions		Name
	cation	anion	
NaCl	Na^{+}	Cl^{-}	sodium chloride
K_2S	K^{+}	S^{2-}	potassium sulfide
MgO	Mg^{2+}	O^{2-}	magnesium oxide
CaI_2	Ca^{2+}	I^{-}	calcium iodide
Al_2O_3	Al^{3+}	O^{2-}	aluminum oxide

Names of Some Common Ions

Group Number	Formula of Ion	Name of Ion	Group Number	Formula of Ion	Name of Ion
	Metals			**Nonmetals**	
1A (1)	Li^+	Lithium	5A (15)	N^{3-}	Nitride
	Na^+	Sodium		P^{3-}	Phosphide
	K^+	Potassium	6A (16)	O^{2-}	Oxide
2A (2)	Mg^{2+}	Magnesium		S^{2-}	Sulfide
	Ca^{2+}	Calcium	7A (17)	F^-	Fluoride
	Ba^{2+}	Barium		Cl^-	Chloride
3A (3)	Al^{3+}	Aluminum		Br^-	Bromide
				I^-	Iodide

Learning Check

Write the formulas and names for compounds of the following ions:

	Br^-	S^{2-}	N^{3-}
Na^+			
Al^{3+}			

Solution

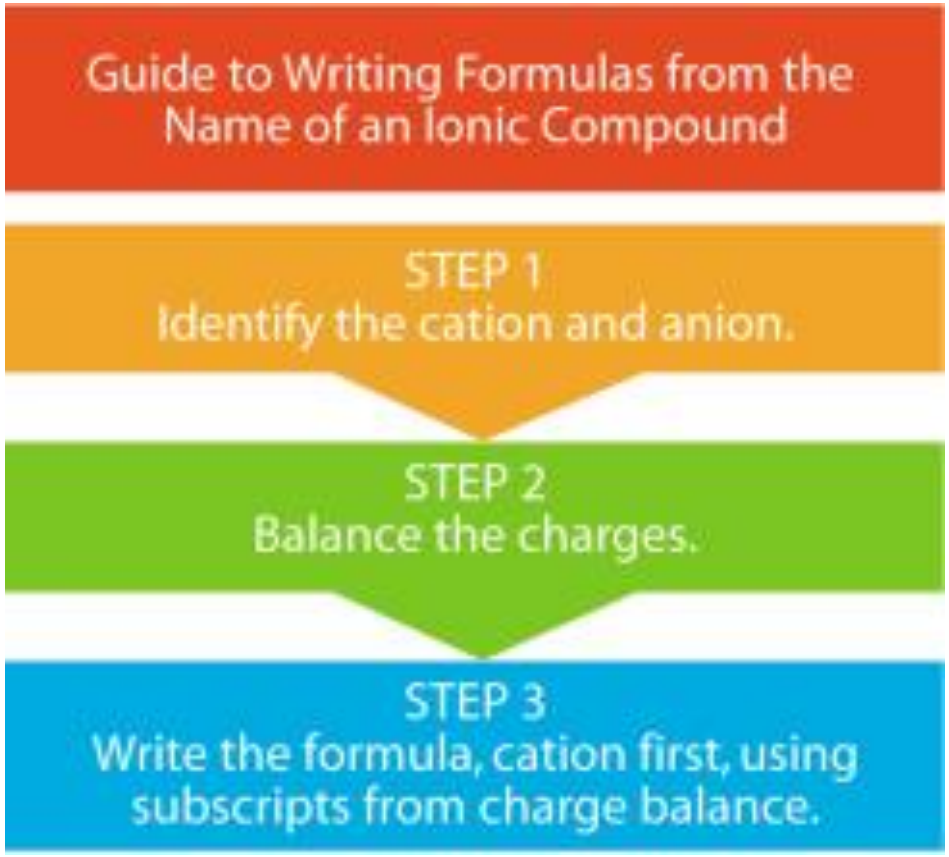
	Br^-	S^{2-}	N^{3-}
Na^+	$NaBr$ sodium bromide	Na_2S sodium sulfide	Na_3N sodium nitride
Al^{3+}	$AlBr_3$ aluminum bromide	Al_2S_3 aluminum sulfide	AlN aluminum nitride

Naming Variable Charge Metals

Transition metals with two different ions use a **Roman numeral** after the name of the metal to indicate ionic charge.

$FeCl_2$	iron(II) chloride
$FeCl_3$	iron(III) chloride
Cu_2S	copper(I) sulfide
$CuCl_2$	copper(II) chloride
$SnCl_2$	tin(II) chloride
$PbBr_4$	lead(IV) bromide

Guide to Writing Formulas from the Name



Writing Formulas from names

Write a formula for potassium sulfide.

1. Identify the cation and anion.
   potassium = K^+
   sulfide = S^{2-}
2. Balance the charges.
   K^+ S^{2-}
   K^+
   2(1+) + 1(2-) = 0

3. 2 K^+ and 1 S^{2-} = **K_2S**

Orbitals

- Electron Configurations can be done in several ways
  - Drawing shells that show the 2-8-8-18 pattern (like I have done on the board)
  - Using Lewis Dot Diagrams to show valence electrons
  - Showing orbital configurations

Orbital configuration pattern

- The electron cloud is made up of orbitals or shells.
- Each orbital can only hold so many electrons before you have to move into another shell
- You can tell which orbital you are in by where you are on the periodic table.

How they work

- Orbitals are labeled as S, P, or D
- S can hold 2
- P can hold 6
- D can hold 10
- You cannot move to the next orbital until you have filled the one you are on.

The order it is in goes like this:

- 1s, 2s, 2p, 3s, 3p, 4s, 3d, 4p, 5s, 4d, 5p, 6s (that is as far as we will go….)
- So if an element had 6 electrons (Carbon), it's configuration would be
- $1s^2\ 2s^2\ 2p^2$
- Each S orbital had to be filled before moving to the next. There are only 2 in the P orbital because there were only 2 left
- If it was Nitrogen, what would it look like?

Polyatomic Ions

Polyatomic Ions

A **polyatomic ion**

- is a group of atoms.
- has an overall ionic charge.

Some examples of polyatomic ions are

NH_4^+	ammonium	OH^-	hydroxide
NO_3^-	nitrate	NO_2^-	nitrite
CO_3^{2-}	carbonate	PO_4^{3-}	phosphate
HCO_3^-	hydrogen carbonate (bicarbonate)		

Names and Formulas of Common Polyatomic Ions

Nonmetal	Formula of Ion[a]	Name of Ion
Hydrogen	OH^-	Hydroxide
Nitrogen	NH_4^+	Ammonium
	NO_3^-	Nitrate
	NO_2^-	Nitrite
Chlorine		
	ClO_3^-	Chlorate
	ClO_2^-	Chlorite
Carbon	CO_3^{2-}	Carbonate
	HCO_3^-	Hydrogen carbonate (or bicarbonate)
	CN^-	Cyanide
	$C_2H_3O_2^-(CH_3COO^-)$	Acetate

Names and Formulas of Common Polyatomic Ions

Nonmetal	Formula of Ion[a]	Name of Ion
Sulfur	SO_4^{2-}	**Sulfate**
	HSO_4^-	Hydrogen sulfate (or bisulfate)
	SO_3^{2-}	Sulfite
	HSO_3^-	Hydrogen sulfite (or bisulfite)
Phosphorus	PO_4^{3-}	**Phosphate**
	HPO_4^{2-}	Hydrogen phosphate
	$H_2PO_4^-$	Dihydrogen phosphate
	PO_3^{3-}	Phosphite
Chromium	CrO_4^{2-}	**Chromate**
	$Cr_2O_7^{2-}$	Dichromate
Manganese	MnO_4^-	Permanganate

Naming Compounds with Polyatomic Ions

- The positive ion is named first followed by the name of the polyatomic ion.

$NaNO_3$	sodium **nitrate**
K_2SO_4	potassium **sulfate**
$Fe(HCO_3)_3$	iron(III) **bicarbonate**
	or iron(III) **hydrogen carbonate**
$(NH_4)_3PO_3$	ammonium **phosphite**

Writing Formulas with Polyatomic Ions

The formula of an ionic compound

- containing a polyatomic ion must have a charge balance that equals zero (0).

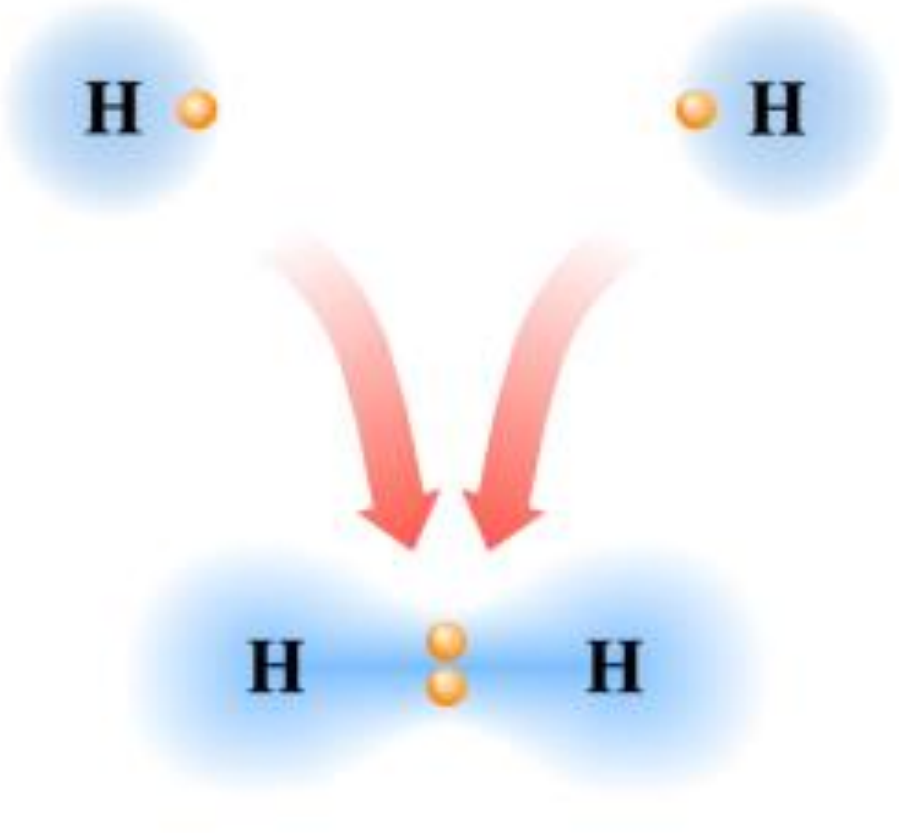
  Na^+ and $\mathbf{NO_3^-}$ → $Na\mathbf{NO_3}$

- with two or more polyatomic ions has the polyatomic ions in parentheses.

  Mg^{2+} and $2NO_3^-$ → $Mg\mathbf{(NO_3)}_2$

  subscript 2 for charge balance

Covalent Compounds



Covalent Bonds

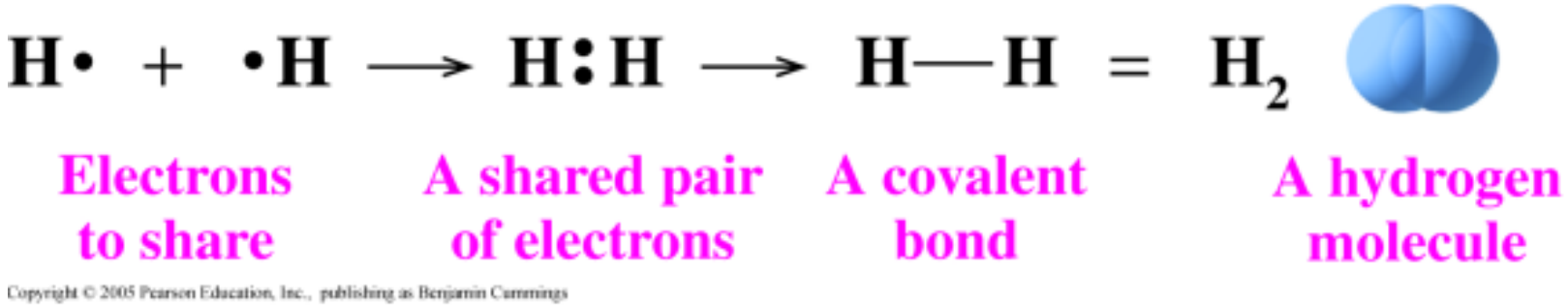
Covalent bonds form

- when atoms **share electrons** to complete octets.
- between two nonmetal atoms.
- between nonmetal atoms from Groups 4A(14), 5A(15), 6A(16), and 7A(17).

Hydrogen Molecule

A hydrogen molecule

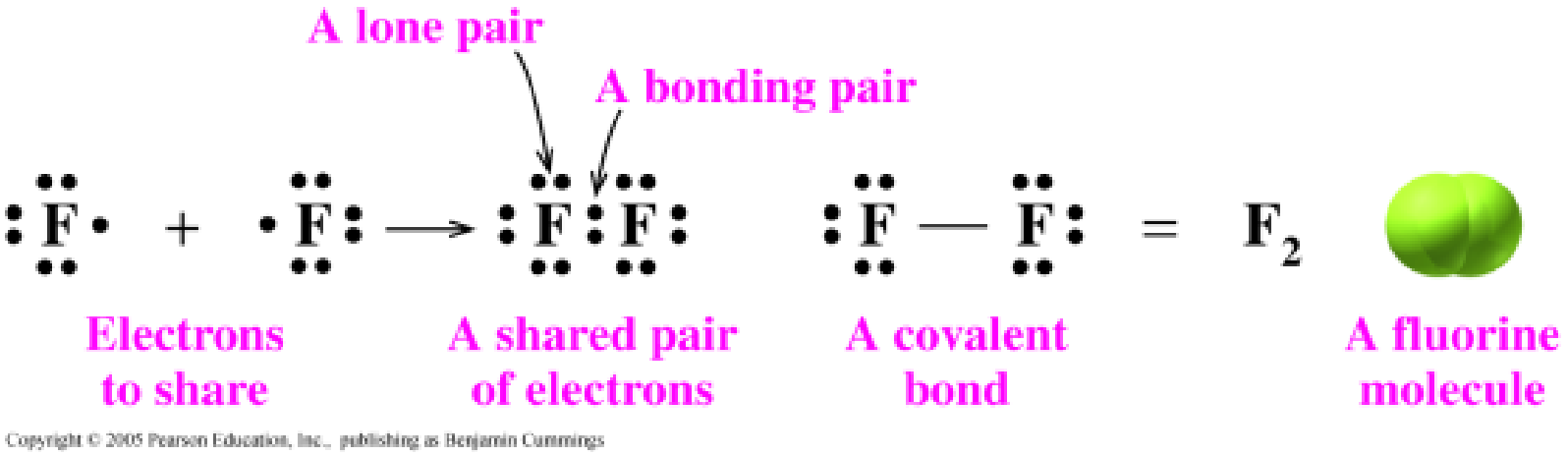
- is stable with two electrons (like helium).
- has a shared pair of electrons.



Forming Octets in Molecules

In a fluorine, F_2, molecule, each F atom

- shares one electron.
- attains an octet.



Naming Covalent Compounds

To name covalent compounds

- **STEP 1:** Name the first nonmetal as an element.
- **STEP 2:** Name the second nonmetal with an *ide* ending.
- **STEP 3:** Use **prefixes** to indicate the number of atoms (subscript) of each element.

Table4.12 **Prefixes Used in Naming Covalent Compounds**

Number of Atoms	Prefix
1	Mono
2	Di
3	Tri
4	Tetra
5	Penta
6	Hexa
7	Hepta
8	Octa
9	Nona
10	Deca

Naming Covalent Compounds

What is the name of SO_3?

1. The first nonmetal is S sulfur.
2. The second nonmetal is O named ox*ide.*
3. The subscript 3 of O is shown as the prefix **tri**.

SO_3 → sulfur **tri**oxide

The subscript 1 (for S) or *mono* is understood.

Formulas and Names of Some Covalent Compounds

Formula	Name	Commercial Uses
CS_2	carbon disulfide	Manufacture of rayon
CO_2	carbon dioxide	Carbonation of beverages, fire extinguishers propellant in aerosols, dry ice
SiO_2	silicon dioxide	Manufacture of glass, computer parts
NCl_3	nitrogen trichloride	Bleaching of flour in some countries (prohibited in U.S.)
SO_2	sulfur dioxide	Preserving fruits, vegetables; disinfectant in breweries; bleaching textiles
SO_3	sulfur trioxide	Manufacture of explosives
SF_6	sulfur hexafluoride	Electrical circuits (insulation)
ClO_2	chlorine dioxide	Bleaching pulp (for making paper), flour, leather
ClF_3	chlorine trifluoride	Rocket propellant

Learning Check

Select the correct name for each compound.

A. $SiCl_4$
1) silicon chloride
2) tetrasilicon chloride
3) silicon tetrachloride

B. P_2O_5
1) phosphorus oxide
2) phosphorus pentoxide
3) diphosphorus pentoxide

C. Cl_2O_7
1) dichlorine heptoxide
2) dichlorine oxide
3) chlorine heptoxide

Name the following compounds

A. $Ca_3(PO_4)_2$

ionic Ca^{2+} PO_4^{3-} calcium phosphate

B. $FeBr_3$

ionic Fe^{3+} Br^- iron(III) bromide

C. SCl_2

covalent 1S 2 Cl sulfur dichloride

D. Cl_2O

covalent 2 Cl 1 O dichlorine monoxide

Write the formulas for the following:

A. calcium nitrate

Ca^{2+}, NO_3^- $Ca(NO_3)_2$

B. boron trifluoride

1 B, 3 F BF_3

C. aluminum carbonate

Al^{3+}, CO_3^{2-} $Al_2(CO_3)_3$

D. dinitrogen tetroxide

2 N, 4 O N_2O_4

Practice questions

Hydrates

- An ionic compound with water molecules attached to it.
- An example:
  - $CaSO_4 \cdot 2H_2O$
  - This is called calcium sulfate dihydrate

  - Notice the prefix is added to the word ***hydrate*** but nothing else.

Removing hydrates

- If enough heat is applied, the water molecule can be broken off the compound. This makes the compound **anhydrous**

- Sometimes that changes the color of the compound

Hygroscopic

- An ionic compound that can easily absorb water molecules from water vapor in the air
- It then becomes a hydrate
- If you have substances that change if the lid is left off, they are probably hygroscopic.

deliquescent

- Compounds that are SOOO hygroscopic they go from a solid to a liquid because they absorb so much water vapor

Organic vs. inorganic

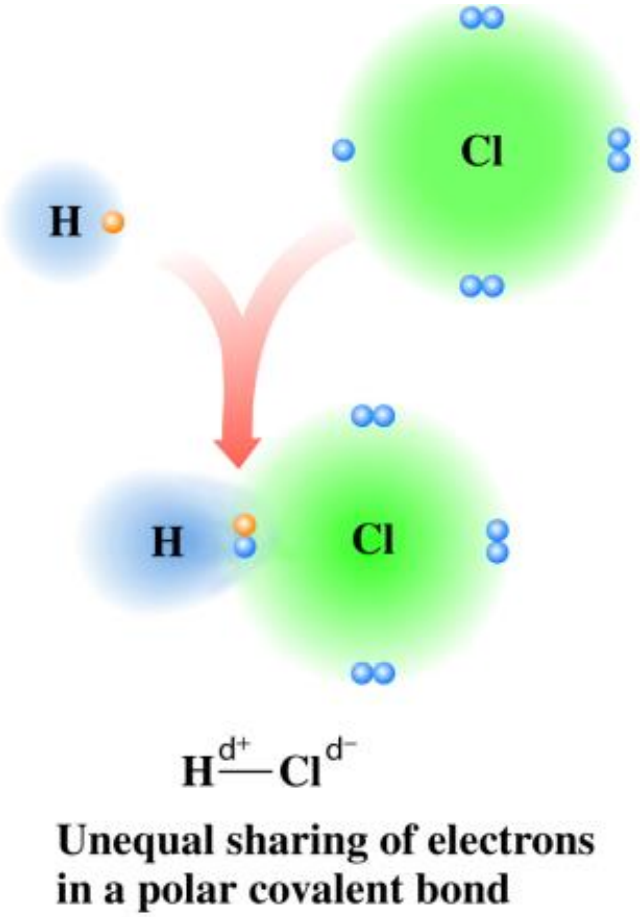
- If a compound has carbon it is an organic compound
- It can be either ionic or covalent

allotropes

- Molecules of a single element that have more than one structure are called allotropes

- Oxygen (O_2) and Ozone (O_3) are allotropes

Electronegativity and Bond Polarity



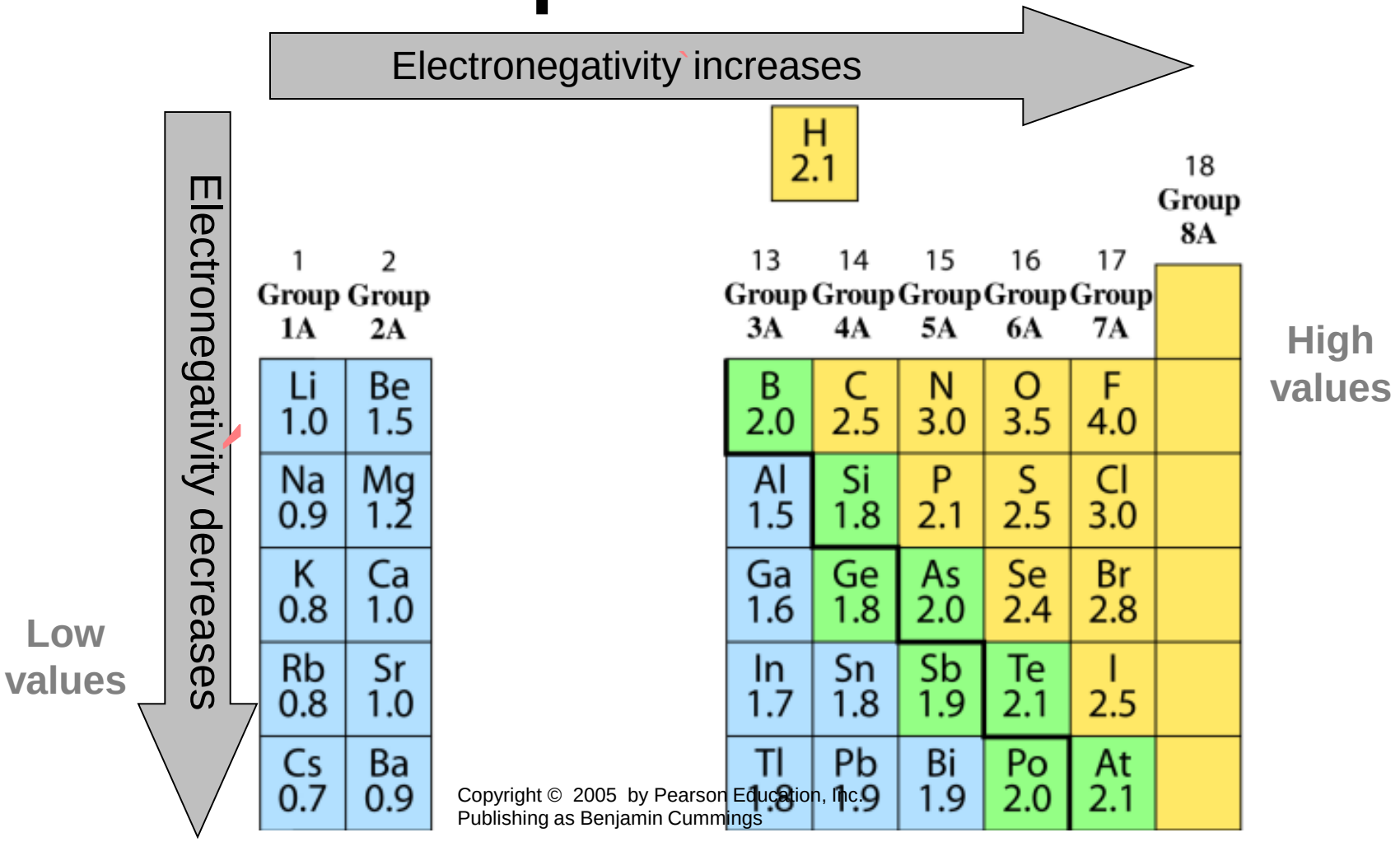
Unequal sharing of electrons in a polar covalent bond

Electronegativity

The **electronegativity value**

- indicates the attraction of an atom for shared electrons.
- increases from left to right going across a period on the periodic table.
- is high for the nonmetals with fluorine as the highest.
- is low for the metals.

Some Electronegativity Values for Group A Elements



Nonpolar Covalent Bonds

A **nonpolar covalent bond**

- occurs between nonmetals.
- is an equal or almost equal sharing of electrons.
- has almost no electronegativity difference (0.0 to 0.4).

Examples:

Atoms	Electronegativity Difference	Type of Bond
N-N	3.0 - 3.0 = **0.0**	Nonpolar covalent
Cl-Br	3.0 - 2.8 = **0.2**	Nonpolar covalent
H-Si	2.1 - 1.8 = **0.3**	Nonpolar covalent

Polar Covalent Bonds

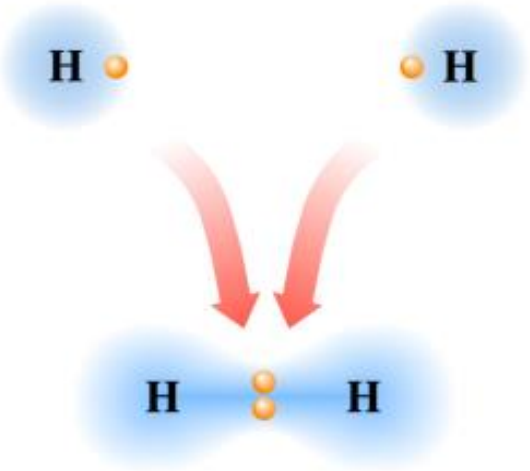
A **polar covalent bond**

- occurs between nonmetal atoms.
- is an unequal sharing of electrons.
- has a moderate electronegativity difference (0.5 to 1.7).

Examples:

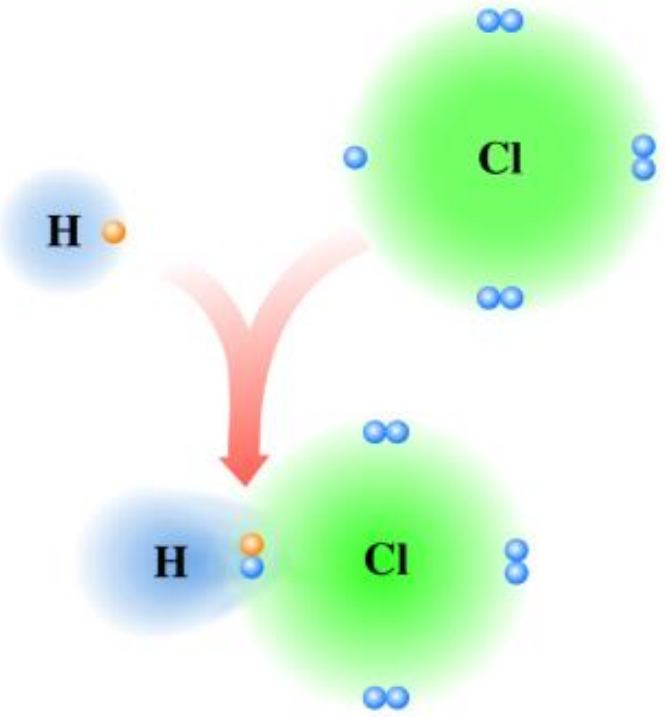
Atoms	Electronegativity Difference	Type of Bond
O-Cl	3.5 - 3.0 = **0.5**	Polar covalent
Cl-C	3.0 - 2.5 = **0.5**	Polar covalent
O-S	3.5 - 2.5 = **1.0**	Polar covalent

Comparing Nonpolar and Polar Covalent Bonds



H—H

Equal sharing of electrons in a nonpolar covalent bond



$H^{\delta+}—Cl^{\delta-}$

Unequal sharing of electrons in a polar covalent bond

Ionic Bonds

An **ionic bond**

- occurs between metal and nonmetal ions.
- is a result of electron transfer.
- has a large electronegativity difference (1.8 or more).

Examples:

Atoms	Electronegativity Difference		Type of Bond
Cl-K	3.0 – 0.8	= **2.2**	Ionic
N-Na	3.0 – 0.9	= **2.1**	Ionic
S-Cs	2.5 – 0.7	= **1.8**	Ionic

Use the electronegativity (see Figure 4.6) difference (Δ) to identify the type of bond between the following as nonpolar covalent (NP), polar covalent (P), or ionic (I).

A. K-N

ΔEN = 2.2 ionic (I) EN: K=0.8, N=3.0

B. N-O

ΔEN = 0.5 polar covalent (P)

C. Cl-Cl

ΔEN = 0.0 nonpolar covalent (NP)

D. H-Cl

ΔEN = 0.9 polar covalent (P)