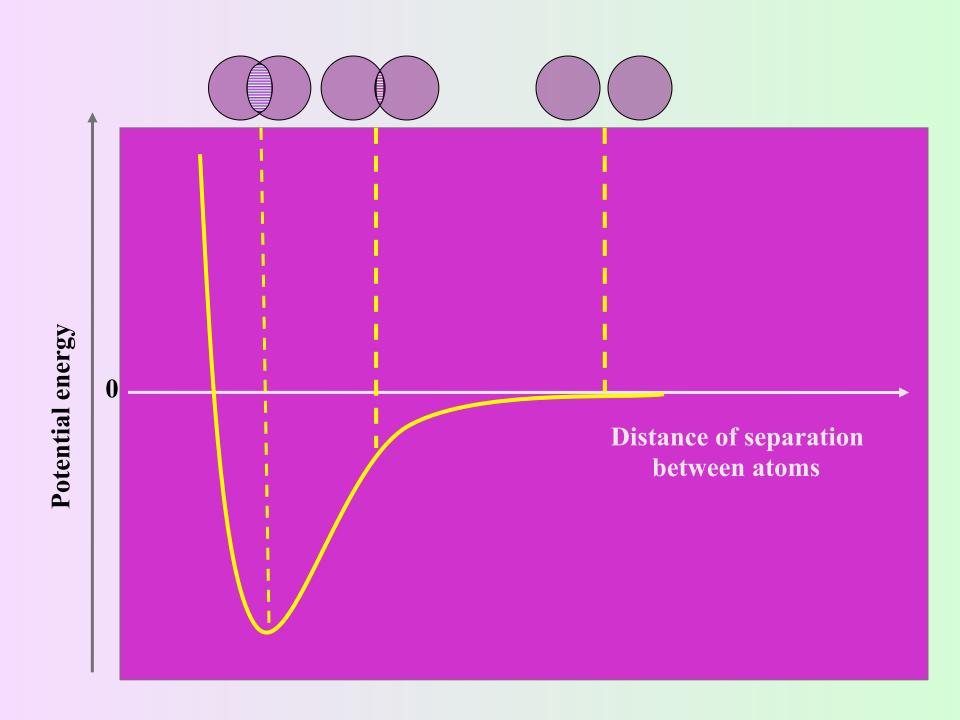
## **Forming Chemical Bonds**

#### Why do atoms form chemical bonds?

so that the system can achieve the lowest possible potential energy

Example covalent bonding in H<sub>2</sub>

 $\mathbf{H} \bullet \mathbf{H}$ 



#### **Chemical Formulas**

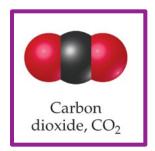












The subscript to the right of the symbol of an element tells the number of atoms of that element in one molecule of the compound.





Methane, CH<sub>4</sub>
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Ethylene,  $C_2H_4$ 

Atoms, Molecules, and lons

#### **Chemical Formulas**

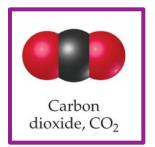














Methane, CH<sub>4</sub>
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Ethylene, C<sub>2</sub>H<sub>4</sub>

The subscript to the right of the symbol of an element tells the number of atoms of that element in one molecule of the compound.



the number 1 is not used as a subscript

Atoms, Molecules, and lons

## **Ions and Ionic Compounds**

## Ionic compounds

Any compound when melted that conducts electricity is considered ionic

Example:  $NaCl_{(s)} \longrightarrow NaCl_{(l)}$ 

NaCl<sub>(s)</sub> is made up of Na+ and Cl- ions

#### **Ions**

When electrons are removed from or added to a neutral atom or molecule, a charged particle called an ion is formed.

Positively charged ions are called cations

Negatively charged ions are called anions

#### **Ionic Bonds**

especially prevalent in compounds formed between group 1A and 2A elements with group 6A and 7A elements.

between Elements with the biggest difference in electronegativity

#### **Ionic Bonds**

especially prevalent in compounds formed between group 1A and 2A elements with group 6A and 7A elements.

between Elements with the biggest difference in electronegativity

## Electronegativity

measure of an element to attract electrons toward itself when bonded to another element

## Electronegativity

**Increases** from left to right in periodic table.

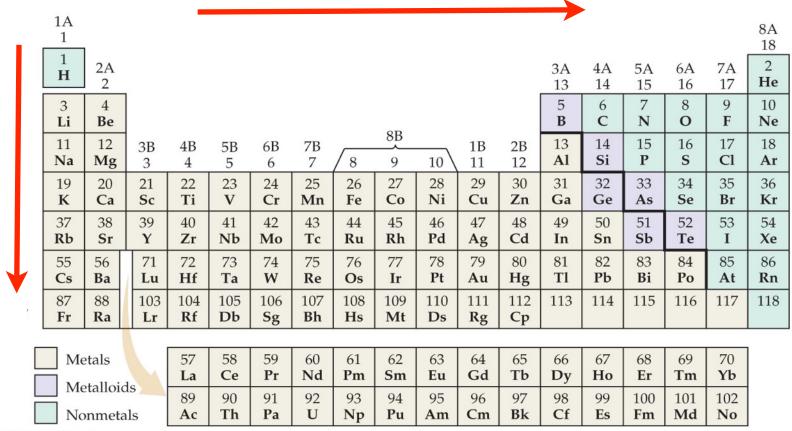
Decreases going down a group.

Fluorine is the most electronegative element.

Francium is the least electronegative element.

# decreasing electronegativity

# increasing electronegativity



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Periodic Properties of the Elements

## most electronegative

	1A 1																	8A 18
	1 <b>H</b>	2A 2											3A 13	4A 14	5A 15	6A 16	7A 17	2 <b>He</b>
	3 Li	4 Be							o.p.				5 <b>B</b>	6 <b>C</b>	7 <b>N</b>	8 <b>O</b>	9 <b>F</b>	10 <b>Ne</b>
	11 <b>N</b> a	12 <b>Mg</b>	3B 3	4B 4	5B 5	6B 6	7B 7	8	8B 9	10	1B 11	2B 12	13 <b>Al</b>	14 <b>Si</b>	15 <b>P</b>	16 <b>S</b>	17 Cl	18 <b>Ar</b>
	19 <b>K</b>	20 <b>Ca</b>	21 <b>Sc</b>	22 <b>Ti</b>	23 <b>V</b>	24 <b>Cr</b>	25 <b>Mn</b>	26 <b>Fe</b>	27 <b>Co</b>	28 <b>Ni</b>	29 <b>Cu</b>	30 <b>Zn</b>	31 <b>Ga</b>	32 <b>Ge</b>	33 <b>As</b>	34 <b>Se</b>	35 <b>Br</b>	36 <b>Kr</b>
	37 <b>Rb</b>	38 <b>Sr</b>	39 <b>Y</b>	40 <b>Zr</b>	41 <b>Nb</b>	42 <b>Mo</b>	43 <b>Tc</b>	44 Ru	45 <b>Rh</b>	46 <b>Pd</b>	47 <b>Ag</b>	48 <b>Cd</b>	49 In	50 <b>Sn</b>	51 <b>Sb</b>	52 <b>Te</b>	53 <b>I</b>	54 <b>Xe</b>
	55 <b>Cs</b>	56 <b>Ba</b>	71 Lu	72 <b>Hf</b>	73 <b>Ta</b>	74 <b>W</b>	75 <b>Re</b>	76 <b>Os</b>	77 <b>Ir</b>	78 <b>Pt</b>	79 <b>Au</b>	80 <b>Hg</b>	81 <b>Tl</b>	82 <b>Pb</b>	83 <b>Bi</b>	84 <b>Po</b>	85 <b>At</b>	86 <b>Rn</b>
	87 <b>Fr</b>	88 <b>Ra</b>	103 <b>Lr</b>	104 <b>Rf</b>	105 <b>Db</b>	106 <b>Sg</b>	107 <b>Bh</b>	108 <b>Hs</b>	109 <b>Mt</b>	110 <b>Ds</b>	111 <b>Rg</b>	112 <b>Cp</b>	113	114	115	116	117	118
																		1
<u>.</u>	ast					59 <b>Pr</b>	60 <b>Nd</b>	61 <b>Pm</b>	62 <b>Sm</b>	63 <b>Eu</b>	64 <b>Gd</b>	65 <b>Tb</b>	66 <b>Dy</b>	67 <b>Ho</b>	68 <b>Er</b>	69 <b>Tm</b>	70 <b>Yb</b>	

least electronegative

59	60	61	62	63	64	65	66	67	68	69	70
<b>Pr</b>	<b>Nd</b>	<b>Pm</b>	<b>Sm</b>	<b>Eu</b>	<b>Gd</b>	<b>Tb</b>	<b>Dy</b>	<b>Ho</b>	<b>Er</b>	<b>Tm</b>	<b>Yb</b>
91 <b>Pa</b>											102 <b>No</b>

Periodic Properties of the Elements

## Pauling Electronegativity Scale

H 2.2

He

Li	Be
0.98	1.57
Na	Mg
0.93	1.31
K	Ca
0.82	1.00
Rb	Sr
0.82	0.95
Cs	Ba
0.79	0.89

B	C	N	O	F	Ne
2.04	2.55	3.04	3.44	3.98	
Al	Si	P	S	Cl	Ar
1.61	1.90	2.19	2.58	3.16	
Ga	Ge	As	Se	Br	Kr
1.81	2.01	2.18	2.55	2.96	2.9
In	Sn	Sb	Te	I	Xe
1.78	1.96	2.05	2.1	2.66	2.6
Tl 2.04	Pb 2.33	Bi 2.02	Po 2.0	At 2.2	Rn

Group	1	2		3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
	1A	2A	Ī	3B	4B	5B	6B	7B		8B		1B	2B	3A	4A	5A	6A	7A	8A
Period																			
1	1 <u>H</u>							•	Me	tals		Met	tallo	ids		<u>Nor</u>	met	tals	2 <u>He</u>
2	3 <u>Li</u>	4 <u>Be</u>												5 <u>B</u>	6 <u>C</u>	7 <u>N</u>	8	9 <u>F</u>	10 <u>Ne</u>
3	11 <u>Na</u>	12 <u>Mg</u>												13 <u>Al</u>	14 <u>Si</u>	15 <u>P</u>	16 <u>S</u>	17 <u>C1</u>	18 <u>Ar</u>
4	19 <u>K</u>	20 <u>Ca</u>		21 Sc	22 <u>Ti</u>	23 <u>Y</u>	24 <u>Cr</u>	25 <u>Mn</u>	26 <u>Fe</u>	27 <u>Co</u>	28 <u>Ni</u>	29 <u>Cu</u>	30 <u>Zn</u>	31 <u>Ga</u>	32 <u>Ge</u>	33 <u>As</u>	34 <u>Se</u>	35 <u>Br</u>	36 <u>Kr</u>
5	37 <u>Rb</u>	38 <u>Sr</u>		39 <u>Y</u>	40 <u>Zr</u>	41 <u>Nb</u>	42 <u>Mo</u>	43 <u>Tc</u>	44 <u>Ru</u>	45 <u>Rh</u>	46 <u>Pd</u>	47 <u>A</u> g	48 <u>Cd</u>	49 <u>In</u>	50 <u>Sn</u>	51 <u>Sb</u>	52 <u>Te</u>	53 <u>I</u>	54 <u>Xe</u>
6	55 <u>Cs</u>	56 <u>Ba</u>	*	71 <u>Lu</u>	72 <u>Hf</u>	73 <u>Ta</u>	74 <u>W</u>	75 <u>Re</u>	76 <u>Os</u>	77 <u>Ir</u>	78 <u>Pt</u>	79 <u>Au</u>	80 <u>Hg</u>	81 <u>T1</u>	82 <u>Pb</u>	83 <u>Bi</u>	84 <u>Po</u>	85 <u>At</u>	86 <u>Rn</u>
7	87 <u>Fr</u>	88 <u>Ra</u>	**	103 <u>Lr</u>	104 <u>Rf</u>	105 <u>Db</u>	106 <u>S</u> g	107 Bh	108 <u>Hs</u>	109 <u>Mt</u>	110 Uun	111 <u>Uuu</u>	112 <u>Uub</u>	113 Uut	114 Uuq	115 Uup	116 Uuh	117 Uus	118 Uuo
lanth	anide	s	*	57 <u>La</u>	58 <u>Ce</u>	59 <u>Pr</u>	60 <u>Nd</u>	61 <u>Pm</u>	62 <u>Sm</u>	63 <u>Eu</u>	64 <u>Gd</u>	65 <u>Tb</u>	66 <u>Dy</u>	67 <u>Ho</u>	68 <u>Er</u>	69 <u>Tm</u>	70 <u>Yb</u>		
acti	nides		**	89 <u>Ac</u>	90 <u>Th</u>	91 <u>Pa</u>	92 <u>U</u>	93 <u>Np</u>	94 <u>Pu</u>	95 <u>Am</u>	96 <u>Cm</u>	97 <u>Bk</u>	98 <u>Cf</u>	99 <u>Es</u>	100 <u>Fm</u>	101 <u>Md</u>	102 <u>No</u>		

In chemical reactions metals tend to lose electrons to nonmetals

#### metals

#### nonmetals

good conductors of heat and electricity

poor conductors

malleable

brittle

ductile

lustrous

tend to lose electrons in chemical reactions

tend to gain electrons in chemical reactions

## **Specific Groups**

# Main groups group numbers identified by suffix A

Group	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
	1A	2A											3A	4A	5A	6A	7A	8A
Period																		
1	1 <u>H</u>																	2 <u>He</u>
2	3 <u>Li</u>	4 <u>Be</u>											5 <u>B</u>	6 <u>C</u>	7 <u>N</u>	8 <u>0</u>	9 <u>F</u>	10 <u>Ne</u>
3	11 <u>Na</u>	12 <u>Mg</u>											13 <u>Al</u>	14 <u>Si</u>	15 <u>P</u>	16 <u>S</u>	17 <u>Cl</u>	18 <u>Ar</u>
4	19 <u>K</u>	20 <u>Ca</u>											31 <u>Ga</u>	32 <u>Ge</u>	33 <u>As</u>	34 <u>Se</u>	35 <u>Br</u>	36 <u>Kr</u>
5	37 <u>Rb</u>	38 <u>Sr</u>											49 <u>In</u>	50 <u>Sn</u>	51 <u>Sb</u>	52 <u>Te</u>	53 <u>I</u>	54 <u>Xe</u>
6	55 <u>Cs</u>	56 <u>Ba</u>											81 <u>T1</u>	82 <u>Pb</u>	83 <u>Bi</u>	84 <u>Po</u>	85 <u>At</u>	86 <u>Rn</u>
7	87 <u>Fr</u>	88 <u>Ra</u>											113 Uut	114 Uuq	115 Uup	116 Uuh	117 Uus	118 Uuo

#### Main group metals

Alkali metals — Alkaline earth metals

Group	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
-	1A	2A	3B	4B	5B	6B	7B		8B		1B	2B	3A	4A	5A	6A	7A	8A
Period				,				,										
1																		
2	3 <u>Li</u>	4 <u>Be</u>																
3	11 <u>Na</u>	12 <u>Mg</u>											13 <u>Al</u>					
4	19 <u>K</u>	20 <u>Ca</u>											31 <u>Ga</u>	32 <u>Ge</u>				
5	37 <u>Rb</u>	38 <u>Sr</u>											49 <u>In</u>	50 <u>Sn</u>	51 <u>Sb</u>			
6	55 <u>Cs</u>	56 <u>Ba</u>											81 <u>T1</u>	82 <u>Pb</u>	83 <u>Bi</u>	84 <u>Po</u>		
7	87 <u>Fr</u>	88 <u>Ra</u>																

#### Nonmetals

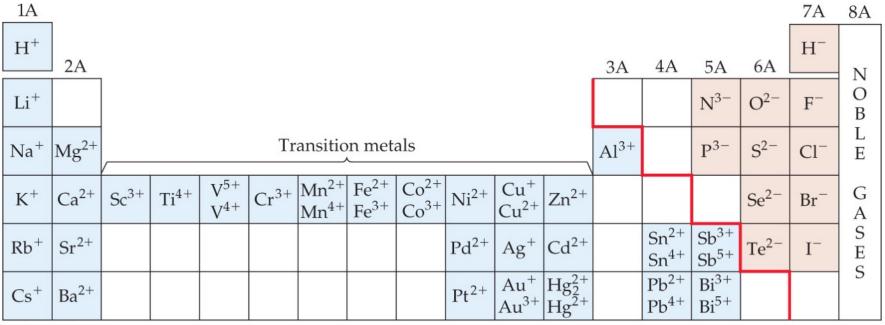
							Ha	alo	ger	ıs_		N	Noble gases						
																$\rightarrow$		_	
Group	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	
	1A	2A	3B	4B	5B	6B	7B		8B		1B	2B	3A	4A	5A	6A	7A	8A	
Period																			
1	1 <u>H</u>																	2 <u>He</u>	
2													5 <u>B</u>	6 <u>C</u>	7 <u>N</u>	<u>0</u>	9 <u>F</u>	10 <u>Ne</u>	
3														14 <u>Si</u>	15 <u>P</u>	16 <u>S</u>	17 <u>Cl</u>	18 <u>Ar</u>	
4															33 <u>A3</u>	34 <u>Se</u>	35 <u>Br</u>	36 <u>Kr</u>	
5																52 <u>Te</u>	53 <u>I</u>	54 <u>Xe</u>	
6																	85 <u>At</u>	86 <u>Rn</u>	
7																			

#### transition metals

Group	1	2		3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
	1A	2A	Ī	3B	4B	5B	6B	7B		8B		1B	2B	3A	4A	5A	6A	7A	8A
Period																			
1	1 <u>H</u>								-1										2 <u>He</u>
2	3 <u>Li</u>	4 <u>Be</u>												5 <u>B</u>	6 <u>C</u>	7 <u>N</u>	8	9 <u>F</u>	10 <u>Ne</u>
3	11 <u>Na</u>	12 <u>Mg</u>							<u></u>					13 <u>Al</u>	14 <u>Si</u>	15 P	16 <u>S</u>	17 <u>C1</u>	18 <u>Ar</u>
4	19 <u>K</u>	20 <u>Ca</u>		21 <u>Sc</u>	22 <u>Ti</u>	23 <u>Y</u>	24 <u>Cr</u>	25 <u>Mn</u>	26 <u>Fe</u>	27 <u>Co</u>	28 <u>Ni</u>	29 <u>Cu</u>	30 <u>Zn</u>	31 <u>Ga</u>	32 <u>Ge</u>	33 <u>As</u>	34 <u>Se</u>	35 <u>Br</u>	36 <u>Kr</u>
5	37 <u>Rb</u>	38 <u>Sr</u>		39 <u>Y</u>	40 <u>Zr</u>	41 <u>Nb</u>	42 <u>Mo</u>	43 <u>Tc</u>	44 <u>Ru</u>	45 <u>Rh</u>	46 <u>Pd</u>	47 <u>A</u> g	48 <u>Cd</u>	49 <u>In</u>	50 <u>Sn</u>	51 <u>Sb</u>	52 <u>Te</u>	53 <u>I</u>	54 <u>Xe</u>
6	55 <u>Cs</u>	56 <u>Ba</u>	*	71 <u>Lu</u>	72 <u>Hf</u>	73 <u>Ta</u>	74 <u>W</u>	75 <u>Re</u>	76 <u>Os</u>	77 <u>Ir</u>	78 <u>Pt</u>	79 <u>Au</u>	80 <u>H</u> g	81 <u>Tl</u>	82 <u>Pb</u>	83 <u>Bi</u>	84 <u>Po</u>	85 <u>At</u>	86 <u>Rn</u>
7	87 <u>Fr</u>	88 <u>Ra</u>	**	103 <u>Lr</u>	104 <u>Rf</u>	105 <u>Db</u>	106 Sg	107 Bh	108 <u>Hs</u>	109 <u>Mt</u>	110 <u>Uun</u>	111 <u>Uuu</u>	112 <u>Uub</u>	113 Uut	114 Uuq	115 Uup	116 Uuh	117 Uus	118 Uuo
lanth	anide	3	*	57 <u>La</u>	58 <u>Ce</u>	59 <u>Pr</u>	60 <u>Nd</u>	61 <u>Pm</u>	62 <u>Sm</u>	63 <u>Eu</u>	64 <u>Gd</u>	65 <u>Tb</u>	66 Dy	67 <u>Ho</u>	68 <u>Er</u>	69 <u>Tm</u>	70 <u>Yb</u>		
acti	nides		**	89 <u>Ac</u>	90 Th	91 Pa	92 <u>U</u>	93 <u>Np</u>	94 Pu	95 Am	96 <u>Cm</u>	97 <u>Bk</u>	98 <u>Cf</u>	99 Es	100 Fm	101 Md	102 <u>No</u>		

#### Metals versus Nonmetals

- Metals tend to form cations.
- Nonmetals tend to form anions.



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## Ionic and Molecular Compounds

**Ionic compounds** are usually formed between metals and nonmetals.

Molecular compounds are usually formed between two nonmetals.

#### Atoms vs Ions



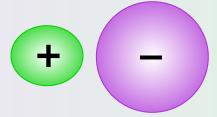
Na: 11 protons;

11 electrons



Cl: 17 protons;

17 electrons

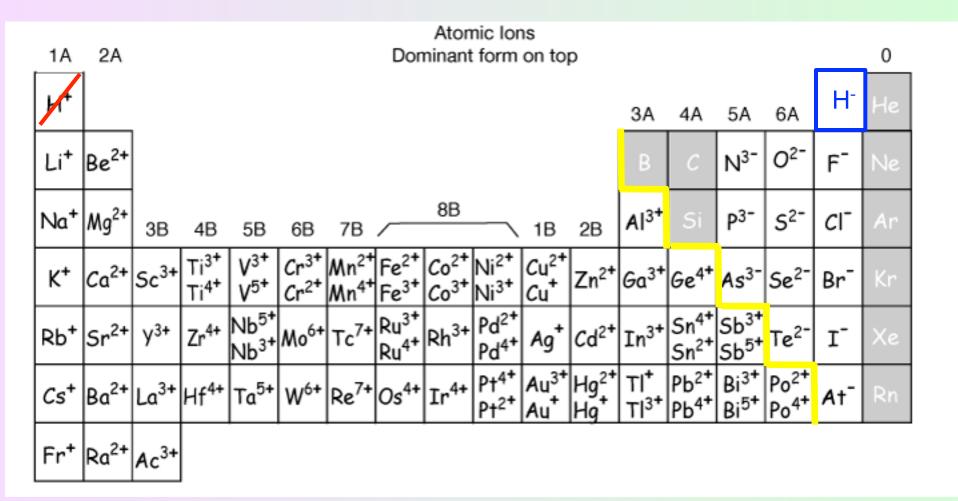


Na+: 11 protons;

10 electrons

Cl: 17 protons;

18 electrons



## Ionic Bonding

electrostatic attraction between oppositely charged ions

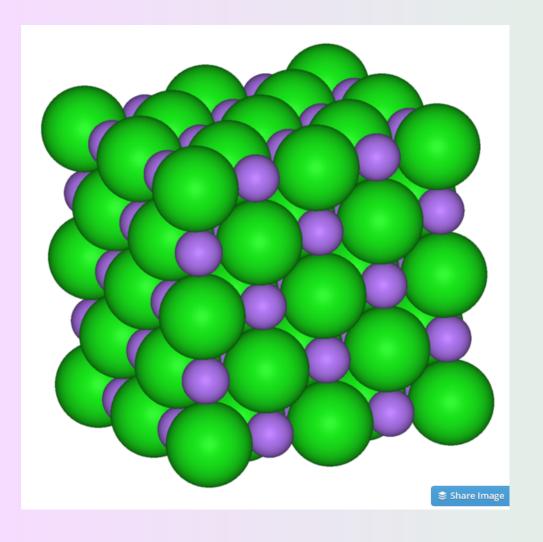


## Ionic Compounds

discrete molecules are not present, so ionic compounds are represented by their empirical formulas

some times referred to as formula units

Empirical formula tells us which elements are present and the simplest whole-number ratio of their atoms.



Solid structure of LiF

**Crystal lattice** 

the ions are packed together to maximize (+) (-) attractions and minimize (+) (+) and (-) (-) repulsions

### Writing Formulas

- compounds are electrically neutral
- The sum of the positive charges of the cations must equal the sum of the negative charges on the anions.
- The subscripts in the chemical formula must be in smallest whole numbers

# $\begin{array}{ccc} & & & Writing Formulas \\ & & & group VA \\ & & & & N \end{array}$

find the charge on the ions

#### Writing Formulas

$$Mg^{2+} \qquad N^{3-} \qquad Mg_3N_2$$

$$Mg^{2+} \qquad N^{3-}$$

$$Mg^{2+} \qquad 2 \qquad N^{3-}$$

$$Mg^{2+} \qquad 2 \qquad N^{3-}$$

$$Mg^{2+}$$

$$Mg^{2+}$$

$$Mg^{2+}$$

$$Mg^{2+}$$

$$-6 = 2(3-)$$

### Writing Formulas

3(2+) = +6

-6 = 2(3-)

## Molecules: Atoms in Combination

## **Definition**

Molecule — is an aggregate of at least two atoms in a definite arrangement held together by chemical forces. structure bonds

## Chemical Formulas

Express the composition of molecules and ionic compounds in terms of the symbols for the elements they contain.

Empirical formula tells us which elements are present and the simplest whole-number ratio of their atoms.

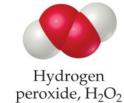
Molecular formula gives the exact number of atoms each element in the compound

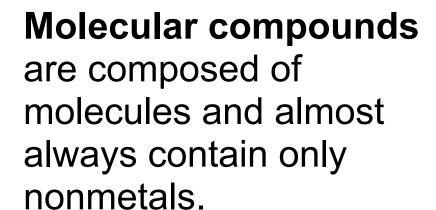
#### **Chemical Formulas**













Carbon monoxide, CO



Carbon dioxide, CO<sub>2</sub>



Methane, CH<sub>4</sub>
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Ethylene, C<sub>2</sub>H<sub>4</sub>

A molecule is not necessarily a compound.

Example

 $\mathbf{H_2} \quad \mathbf{O_2} \quad \mathbf{Cl_2}$ 

A compound is not necessarily molecular.

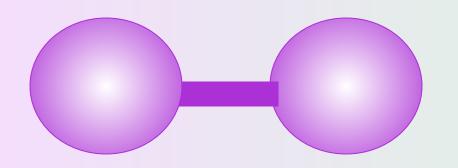
ionic compounds

#### **Diatomic Molecules**

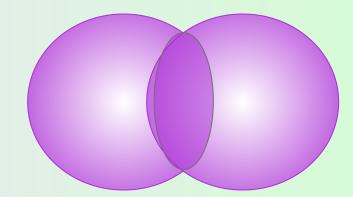
- These seven elements occur naturally as molecules containing two atoms:
  - -HydrogenN<sub>2</sub>
  - -Nitrogen O<sub>2</sub>
  - -Oxygen F<sub>2</sub>
  - -Fluorine Cl<sub>2</sub>
  - -Chlorine Br<sub>2</sub>
  - -Bromine I
  - -lodine

# Hydrogen

the stable form of the element is diatomic a molecule H<sub>2</sub>



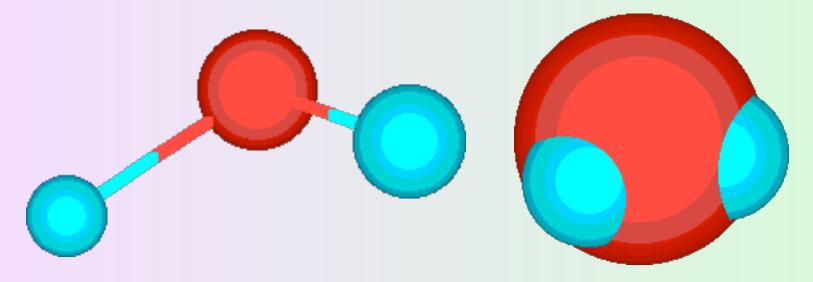
ball-and-stick model



space-filling model

# Water (H<sub>2</sub>O)

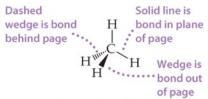
is a polyatomic molecule (contains three atoms connected in the order HOH).



## Types of Formulas

CH<sub>4</sub>
Molecular formula

Structural formula



Perspective drawing

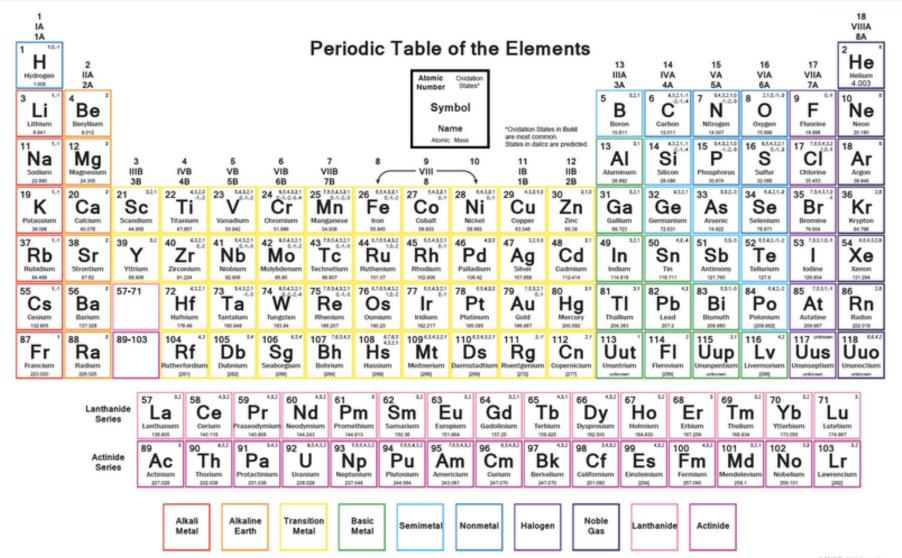


Ball-and-stick model



Space-filling model
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- Structural formulas show the order in which atoms are bonded.
- Perspective drawings also show the three-dimensional array of atoms in a compound.



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### **Common Cations**

TABLE 2.4 • Common Cations*							
Charge	Formula	Name	Formula	Name			
1+	H <sup>+</sup>	hydrogen ion	NH <sub>4</sub> <sup>+</sup>	ammonium ion			
	Li <sup>+</sup>	lithium ion	Cu <sup>+</sup>	copper(I) or cuprous ion			
	Na <sup>+</sup>	sodium ion					
	K <sup>+</sup>	potassium ion					
	Cs <sup>+</sup>	cesium ion					
	Ag <sup>+</sup>	silver ion					
2+	Mg <sup>2+</sup>	magnesium ion	Co <sup>2+</sup>	cobalt(II) or cobaltous ion			
	Ca <sup>2+</sup>	calcium ion	Cu <sup>2+</sup>	copper(II) or cupric ion			
	Sr <sup>2+</sup>	strontium ion	Fe <sup>2+</sup>	iron(II) or ferrous ion			
	Ba <sup>2+</sup>	barium ion	Mn <sup>2+</sup>	manganese(II) or manganous ion			
	$Zn^{2+}$	zinc ion	Hg <sub>2</sub> <sup>2+</sup>	mercury(I) or mercurous ion			
	$Cd^{2+}$	cadmium ion	Hg <sup>2+</sup>	mercury(II) or mercuric ion			
			Ni <sup>2+</sup>	nickel(II) or nickelous ion			
			Pb <sup>2+</sup>	lead(II) or plumbous ion			
			Sn <sup>2+</sup>	tin(II) or stannous ion			
3+	Al <sup>3+</sup>	aluminum ion	Cr <sup>3+</sup>	chromium(III) or chromic ion			
			Fe <sup>3+</sup>	iron(III) or ferric ion			

<sup>\*</sup>The ions we use most often in this course are in boldface. Learn them first. © 2012 Pearson Education, Inc.

### **Common Anions**

TABLE 2.5 • Common Anions*							
Charge	Formula	Name	Formula	Name			
1-	H <sup>-</sup>	hydride ion	$CH_3COO^-$ (or $C_2H_3O_2^-$ )	acetate ion			
	$\mathbf{F}^{-}$	fluoride ion	ClO <sub>3</sub>	chlorate ion			
	Cl <sup>-</sup>	chloride ion	ClO <sub>4</sub>	perchlorate ion			
	Br <sup>-</sup>	bromide ion	NO <sub>3</sub>	nitrate ion			
	I_	iodide ion	$\mathrm{MnO_4}^-$	permanganate ion			
	CN <sup>-</sup>	cyanide ion					
_	OH-	hydroxide ion					
2-	$O^{2-}$	oxide ion	CO <sub>3</sub> <sup>2-</sup>	carbonate ion			
	O <sub>2</sub> <sup>2-</sup> <b>S<sup>2-</sup></b>	peroxide ion	$CrO_4^{2-}$	chromate ion			
	$S^{2-}$	sulfide ion	$Cr_2O_7^{2-}$	dichromate ion			
			SO <sub>4</sub> <sup>2-</sup>	sulfate ion			
3-	$N^{3-}$	nitride ion	PO <sub>4</sub> <sup>3-</sup>	phosphate ion			

<sup>\*</sup>The ions we use most often are in boldface. Learn them first.  ${\it @}\,2012\,{\it Pearson}\,{\it Education},$  inc.