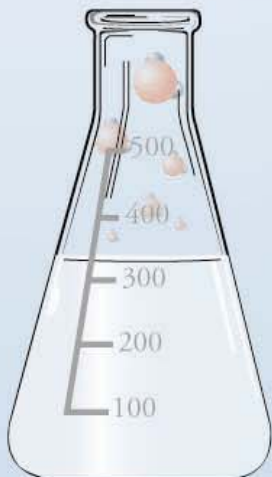
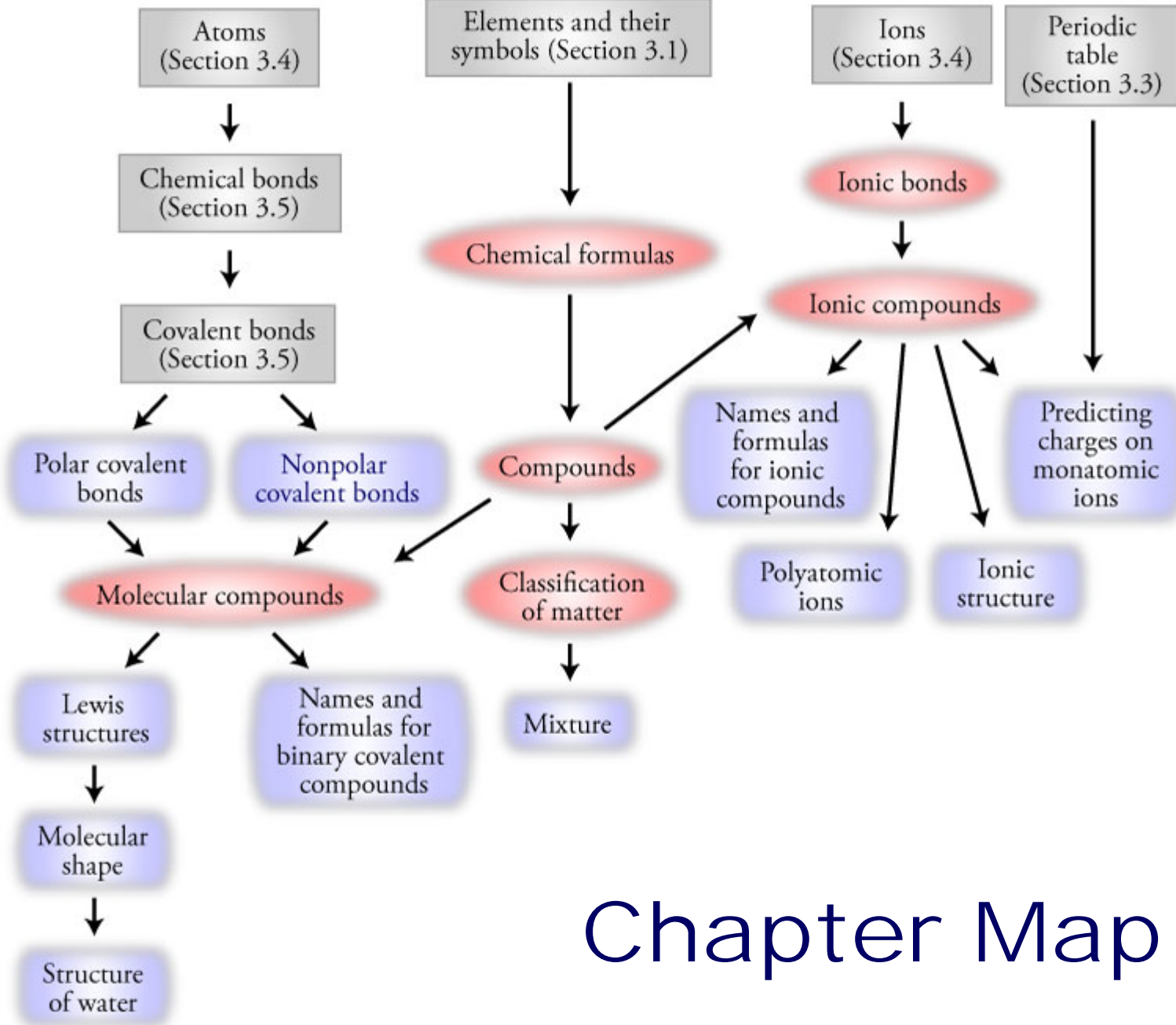


# Chapter 4

## Chemical Compounds

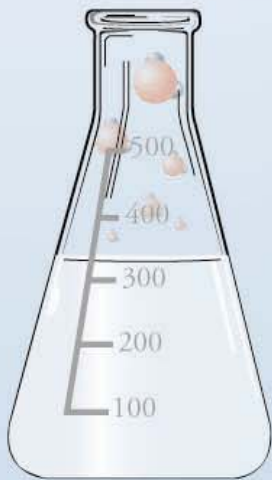




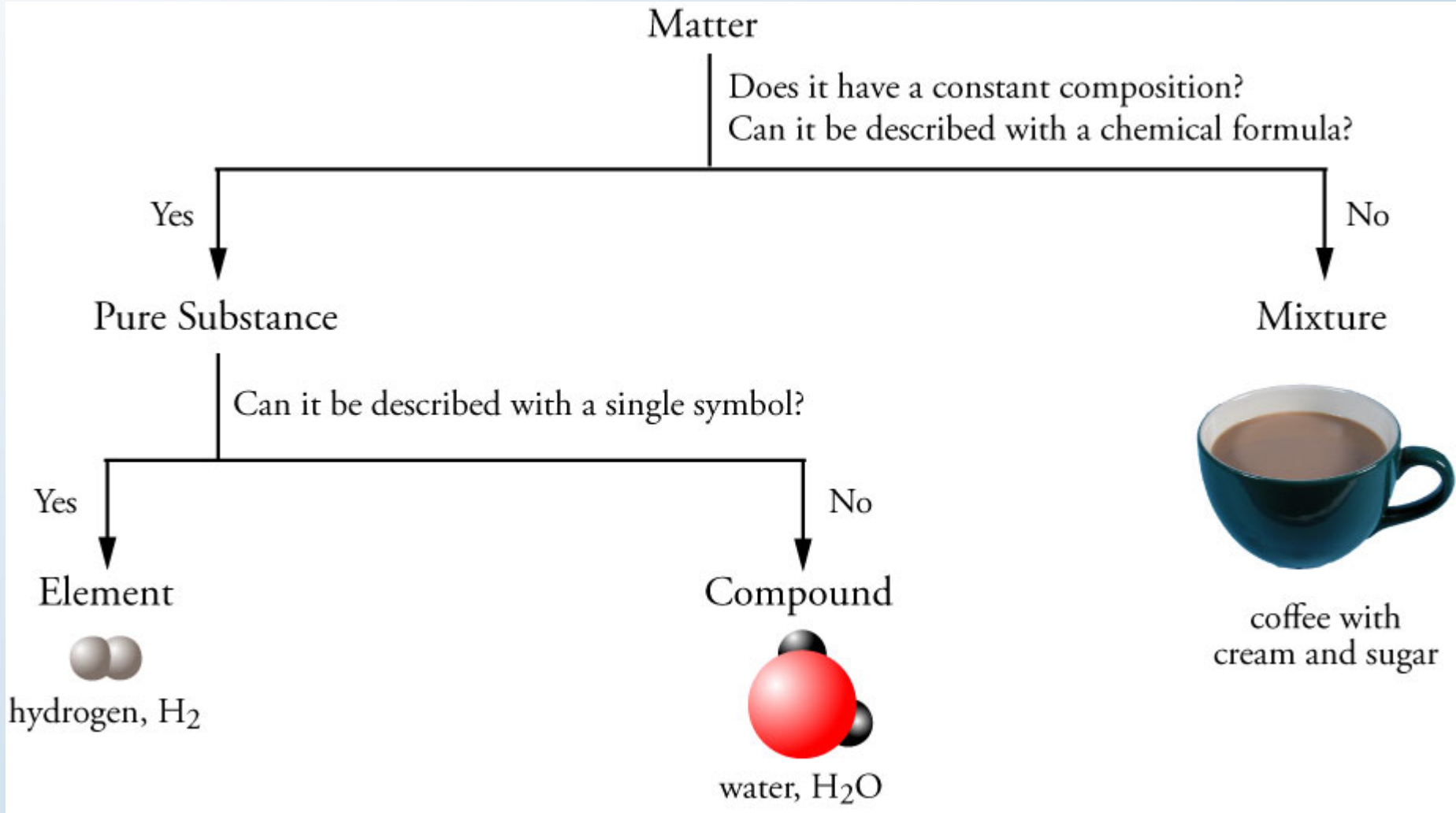
# Chapter Map

# Elements, Compounds, and Mixtures

- **Element:** A substance that cannot be chemically converted into simpler substances; a substance in which all of the atoms have the same number of protons and therefore the same chemical characteristics.
- **Compound:** A substance that contains two or more elements, the atoms of these elements always combining in the same whole-number ratio.
- **Mixture:** A sample of matter that contains two or more pure substances (elements and compounds) and has variable composition.



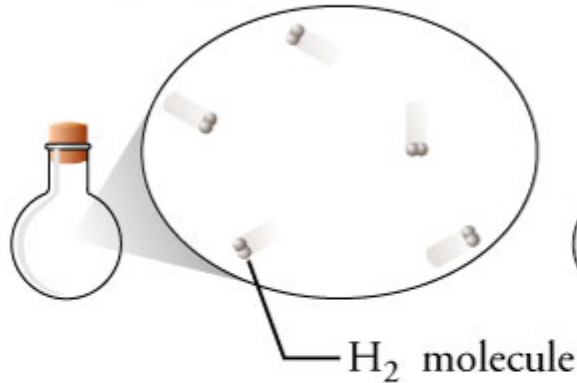
# Classification of Matter



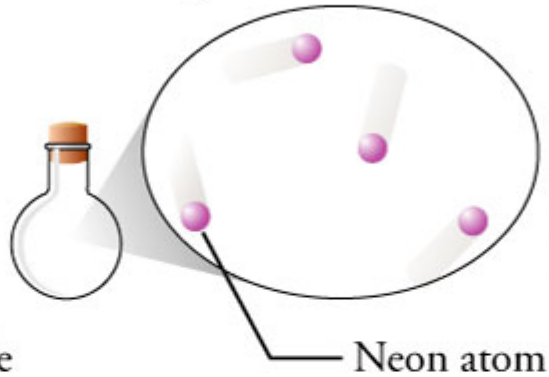
# Elements and Compounds

## ELEMENTS

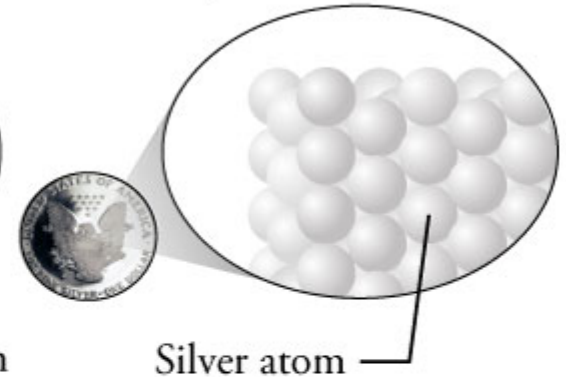
Hydrogen is composed of molecules with 2 hydrogen atoms.



Neon is composed of independent atoms.

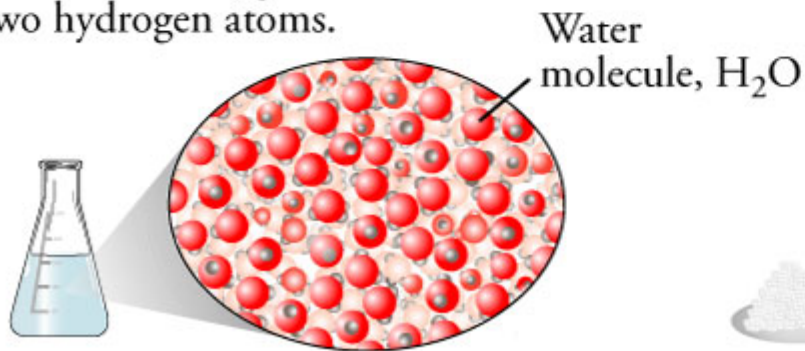


Silver exists as an assembly of silver atoms.

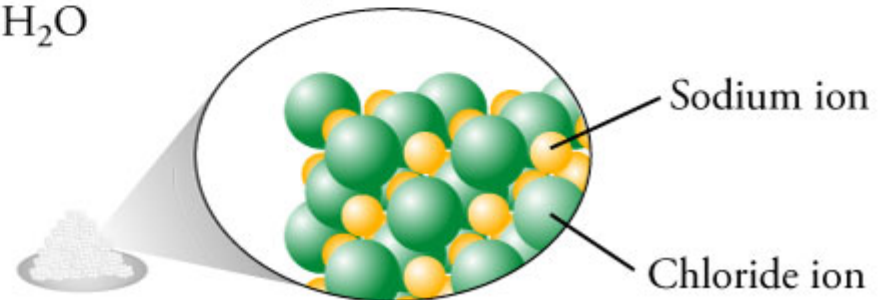


## COMPOUNDS

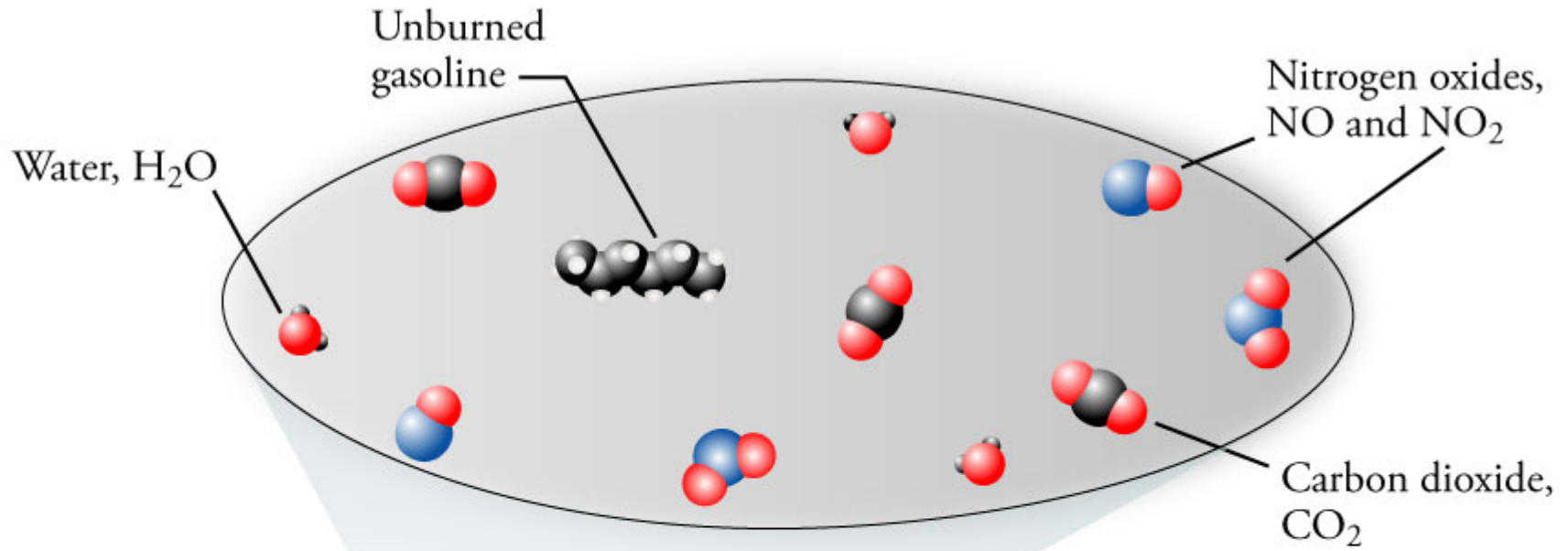
Water is composed of molecules that contain one oxygen atom and two hydrogen atoms.



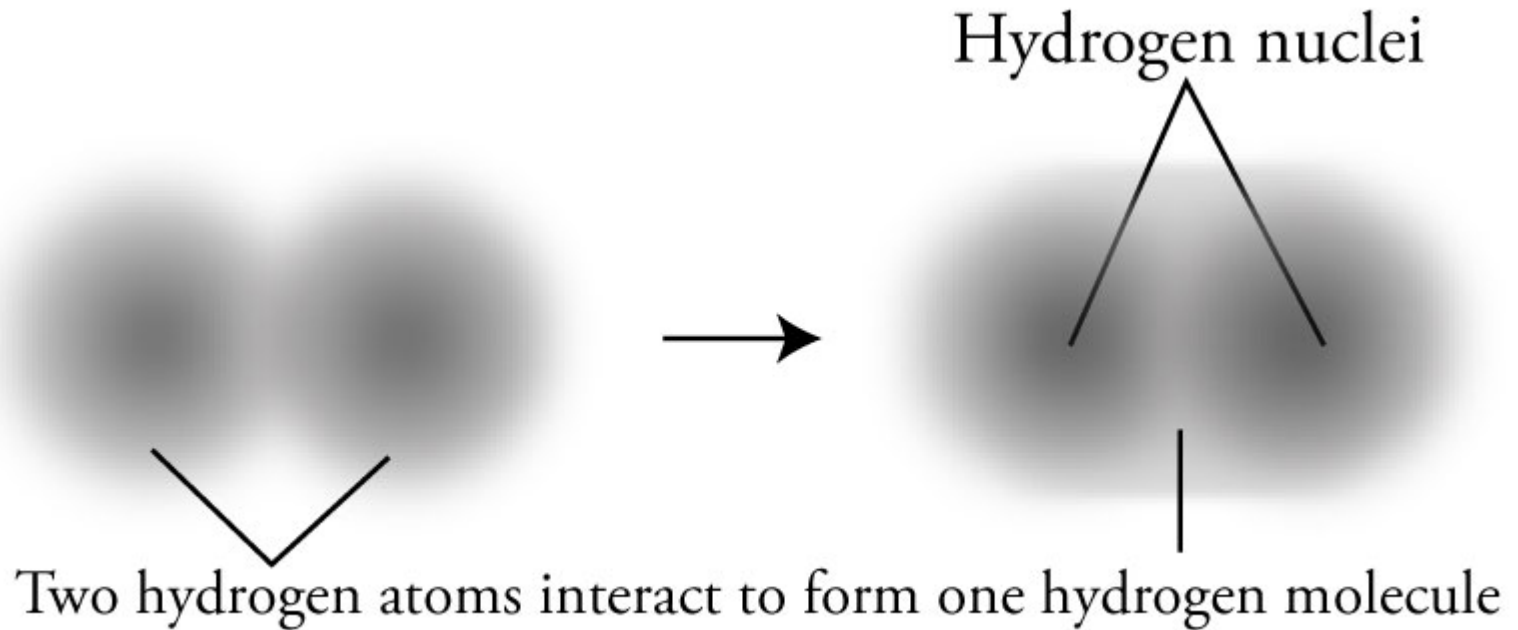
Sodium chloride exists as an assembly of sodium and chloride ions, always in a one-to-one ratio.



# Exhaust - a Mixture



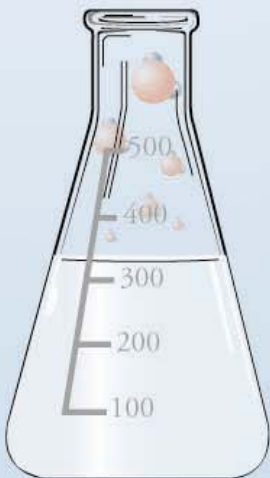
# Covalent Bond Formation





# Covalent Bond

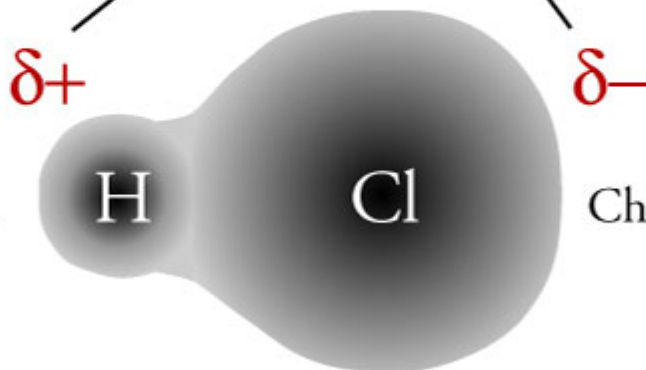
- A link between atoms due to the sharing of two electrons. This bond forms between atoms of two nonmetallic elements.
  - If the electrons are shared equally, there is an even distribution of the negative charge for the electrons in the bond, so there are no partial charges on the atoms. The bond is called a ***nonpolar covalent bond***.
  - If one atom in the bond attracts electrons more than the other atom, the electron negative charge shifts to that atom giving it a partial negative charge. The other atom loses negative charge giving it a partial positive charge. The bond is called a ***polar covalent bond***.





# Polar Covalent Bond

Electrons shift toward the chlorine atom,  
forming partial plus and minus charges.

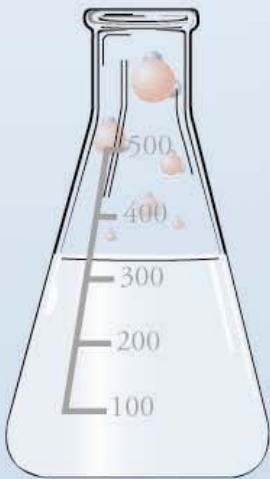


Hydrogen attracts electrons less.

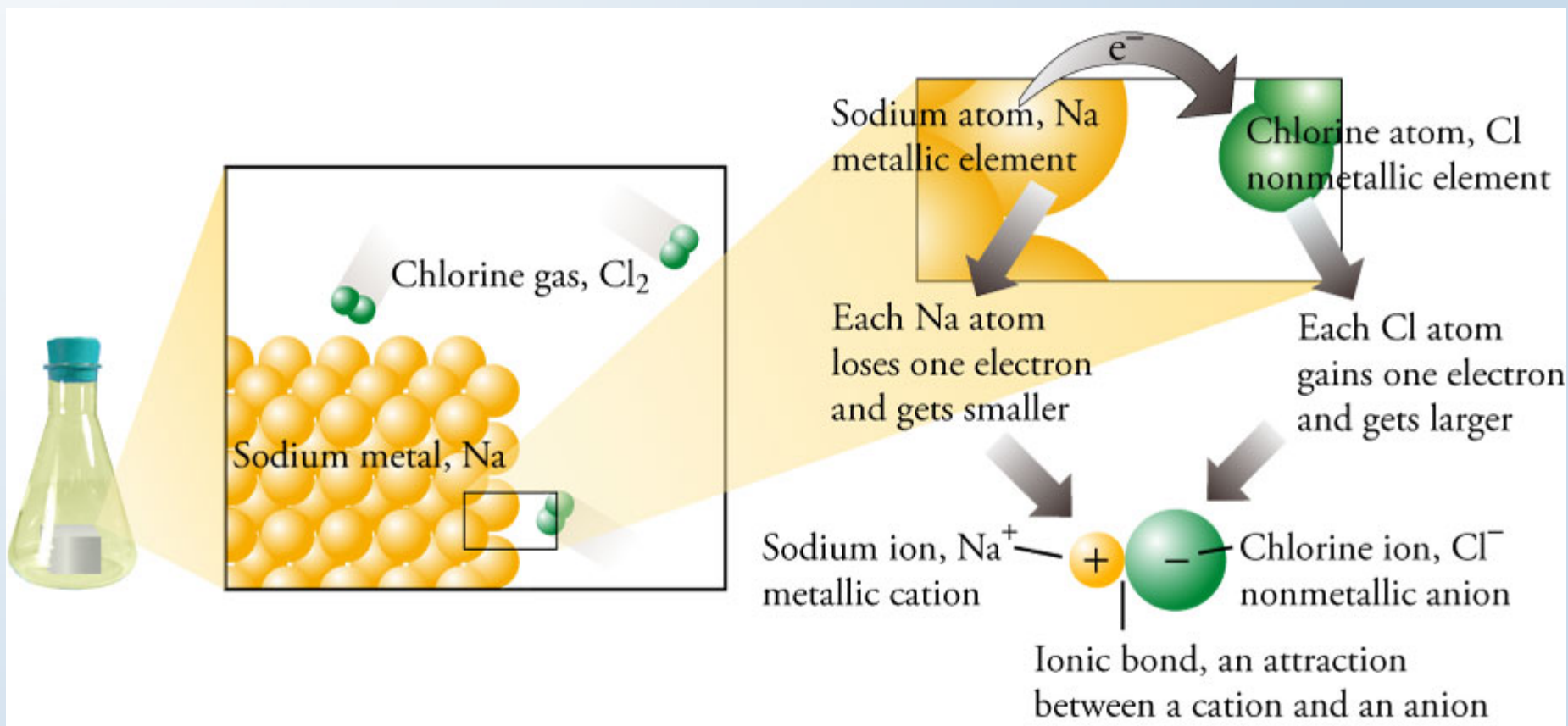
Chlorine attracts electrons more.

# Ionic Bond

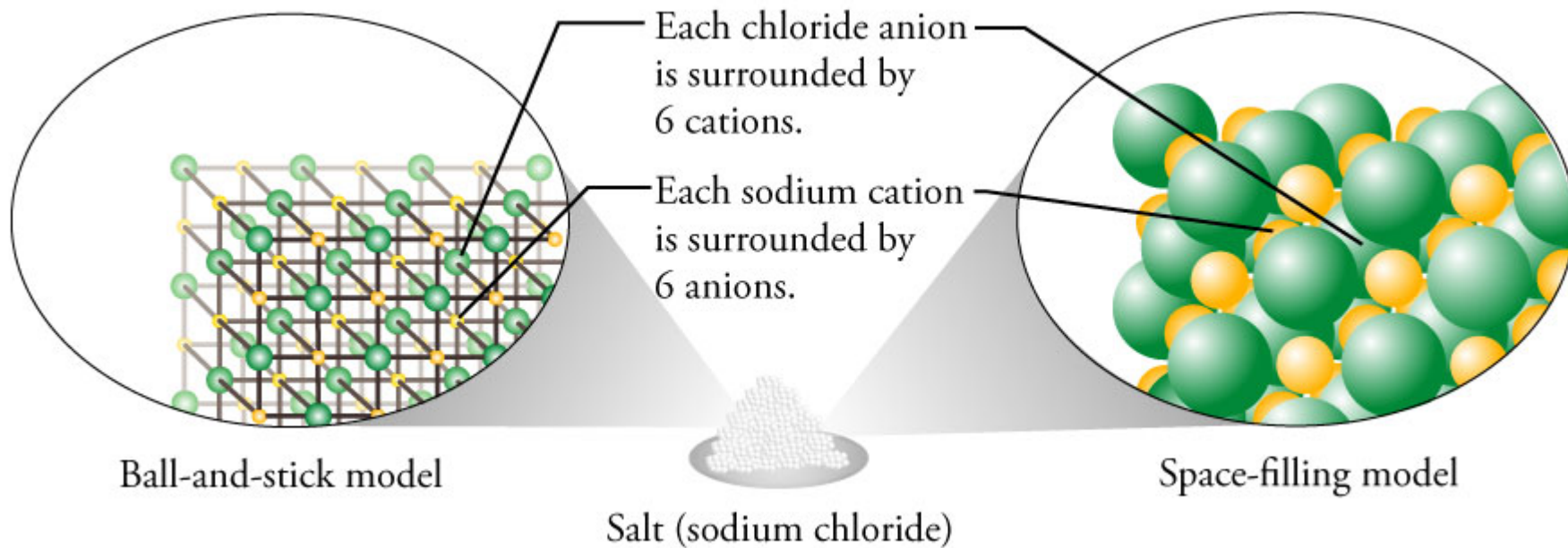
- The attraction between cation and anion.
- Atoms of nonmetallic elements often attract electrons so much more strongly than atoms of metallic elements that one or more electrons are transferred from the metallic atom (forming a positively charged particle or ***cation***), to the nonmetallic atom (forming a negatively charged particle or ***anion***).
- For example, an uncharged chlorine atom can pull one electron from an uncharged sodium atom, yielding  $\text{Cl}^-$  and  $\text{Na}^+$ .



# Ionic Bond Formation



# Sodium Chloride, NaCl, Structure

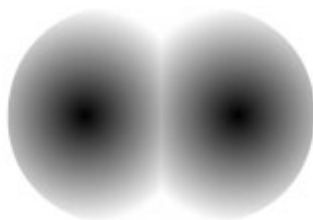


# Bond Types

## Nonpolar Covalent Bond

Equal sharing of electrons

Both atoms attract electrons equally (or nearly so).

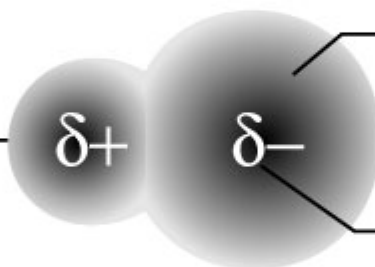


No significant charges form.

## Polar Covalent Bond

Unequal sharing of electrons

Partial positive charge



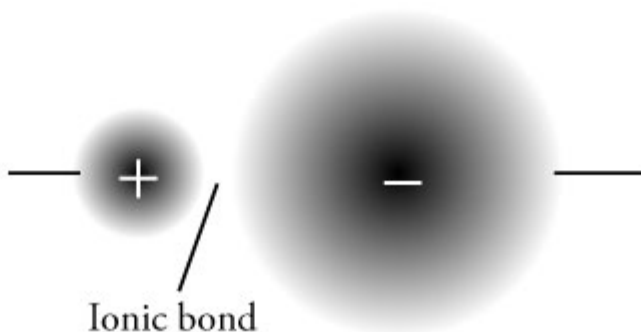
This atom attracts electrons more strongly.

Partial negative charge.

## Ionic Bond

Strong attraction between positive and negative charges.

This atom loses one or more electrons and gains a positive charge.

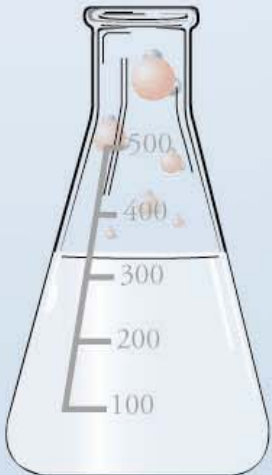


This atom attracts electrons so much more strongly than the other atom that it gains one or more electrons and gains a negative charge.

A decorative border on the left side of the slide consists of several water molecules (H<sub>2</sub>O) represented by a large red sphere (oxygen) and two smaller black spheres (hydrogen) in a bent arrangement. These molecules are scattered from the top left towards the bottom left.

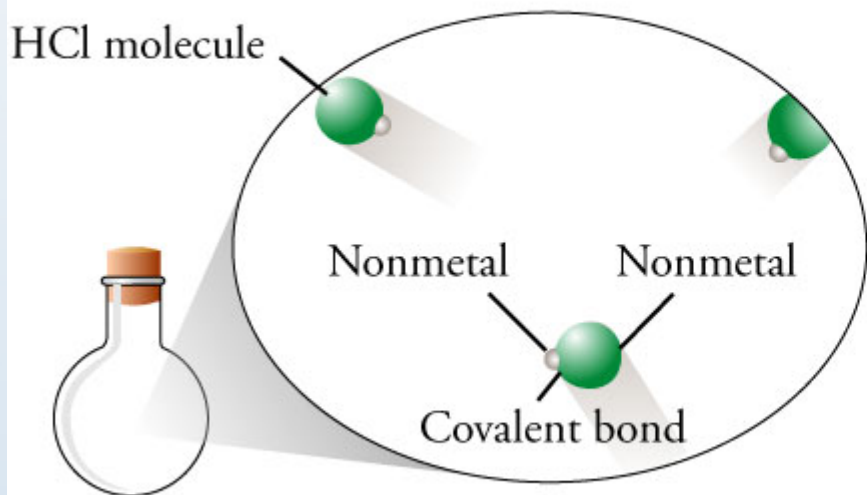
# Types of Compounds

- All nonmetallic atoms usually leads to all covalent bonds, which form molecules. These compounds are called ***molecular compounds***.
- Metal-nonmetal combinations usually lead to ionic bonds and ***ionic compounds***.

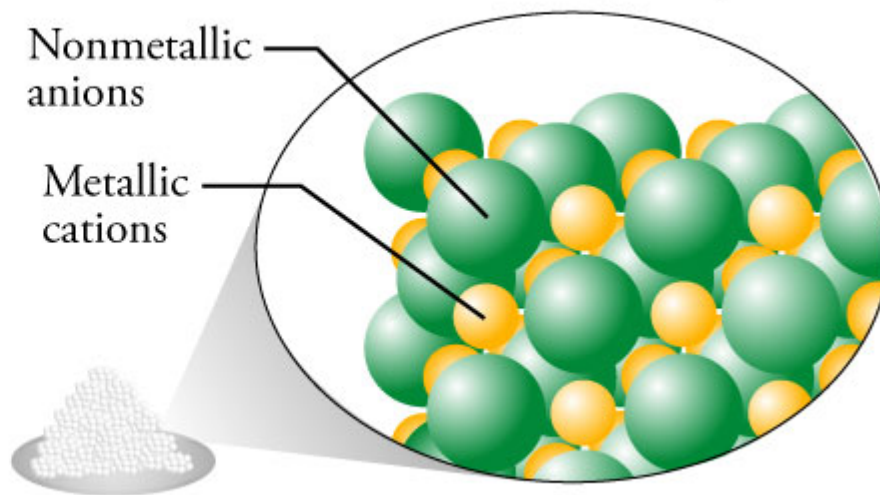


# Classification of Compounds

**Molecular compound**  
Hydrogen chloride, HCl, gas



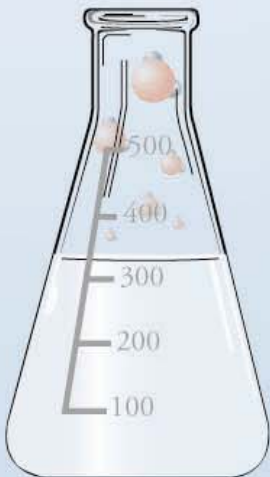
**Ionic compound**  
Sodium chloride, NaCl, solid





# Summary

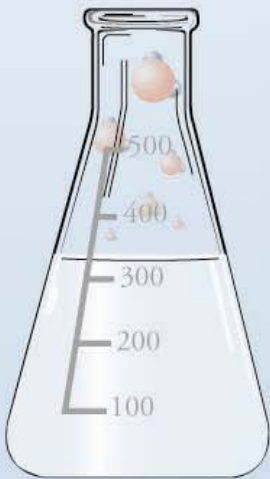
- **Nonmetal-nonmetal** combinations (e.g. HCl)
  - Covalent bonds
  - Molecules
  - Molecular Compound
- **Metal-nonmetal** combinations (e.g. NaCl)
  - Probably ionic bonds
  - Alternating cations and anions in crystal structure
  - Ionic compound





# Valence Electrons

- The valence electrons for each atom are the most important electrons in the formation of chemical bonds.
- The number of valence electrons for the atoms of each element is equal to the element's A-group number on the periodic table.
- Covalent bonds often form to pair unpaired electrons and give the atoms of the elements other than hydrogen and boron eight valence electrons (an octet of valence electrons).

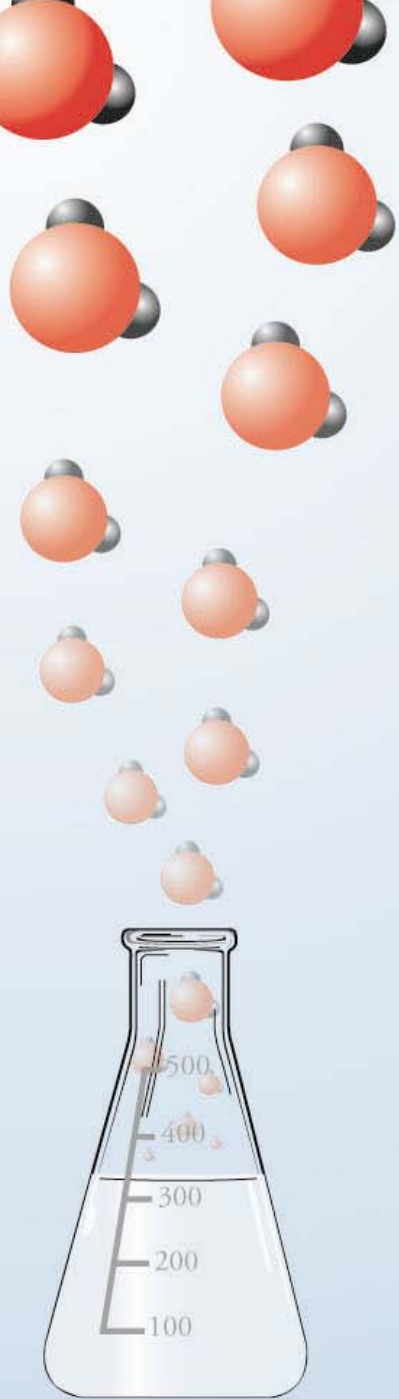


# Valence Electrons and A-Group Numbers

One valence electron

Number of valence electrons equals the A-group number

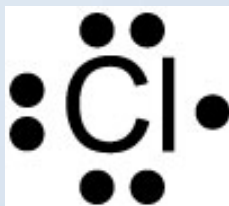
1 H						8A 2 He
	3A 5 B	4A 6 C	5A 7 N	6A 8 O	7A 9 F	10 Ne
			15 P	16 S	17 Cl	18 Ar
			33 As	34 Se	35 Br	36 Kr
				52 Te	53 I	54 Xe



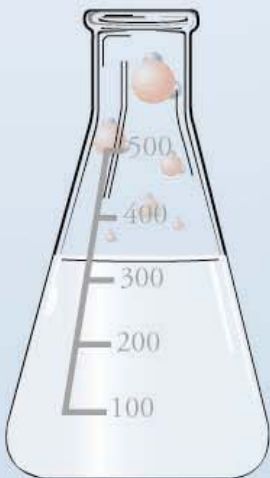


# Electron-Dot Symbols and Lewis Structures

- **Electron-dot symbols** show valence electrons.

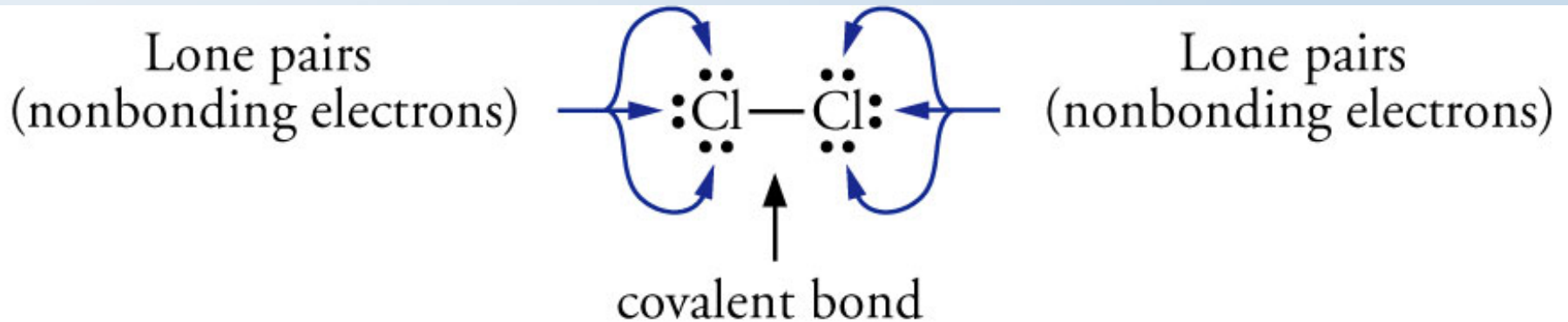


- Nonbonding pairs of valence electrons are called ***lone pairs***.



# Lewis Structures

- **Lewis structures** represent molecules using element symbols, lines for bonds, and dots for lone pairs.



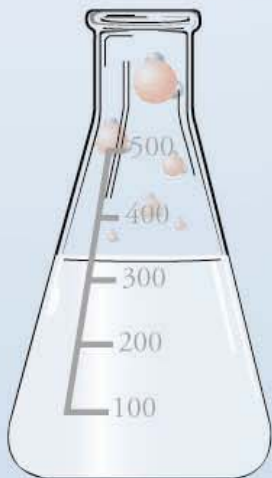
# Most Common Bonding Patterns for Nonmetals

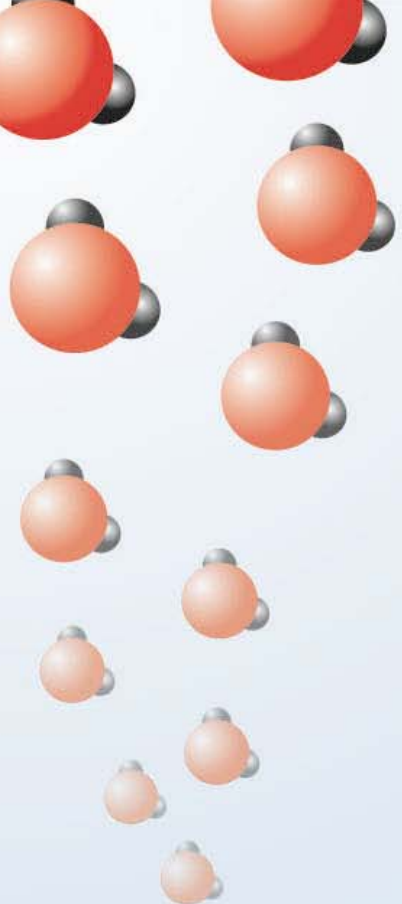
Element	# Bonds	# lone pairs
H	1	0
C	4	0
N, P	3	1
O, S, Se	2	2
F, Cl, Br, I	1	3



# Drawing Lewis Structures

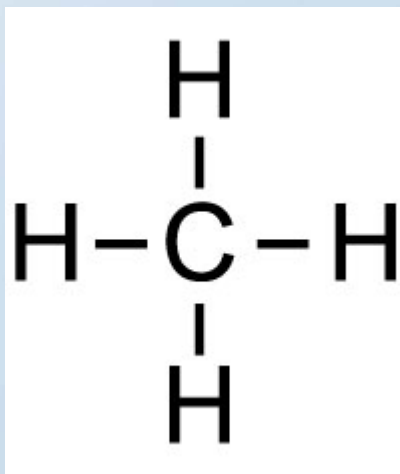
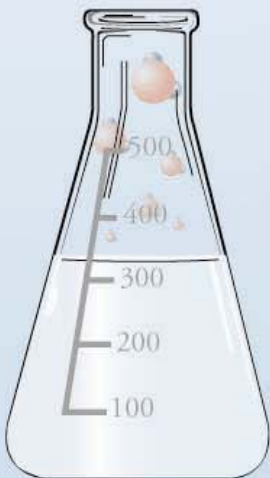
- Chapter 12 describes procedure that allows you to draw Lewis structures for many different molecules.
- Many Lewis structures can be drawn by attempting to give each atom in a molecule its most common bonding pattern.



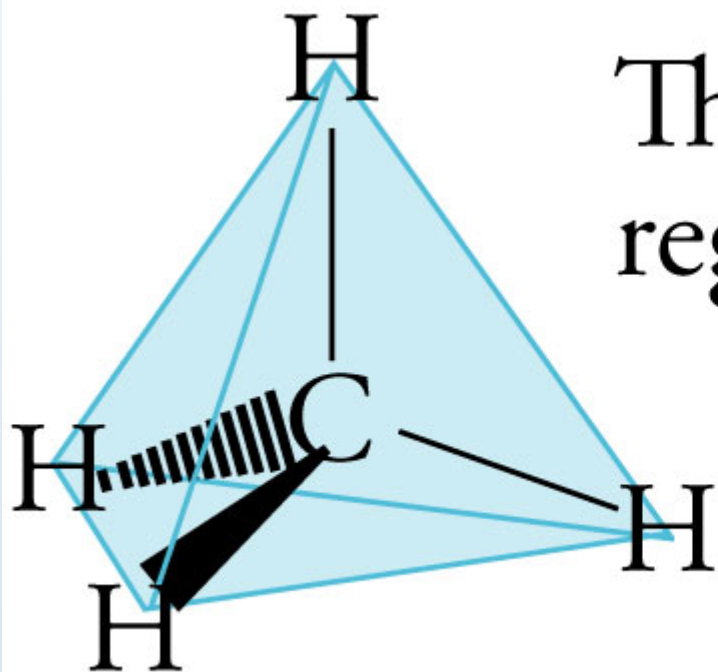


# Lewis Structure for Methane, CH<sub>4</sub>

- Carbon atoms usually have 4 bonds and no lone pairs.
- Hydrogen atoms have 1 bond and no lone pairs.



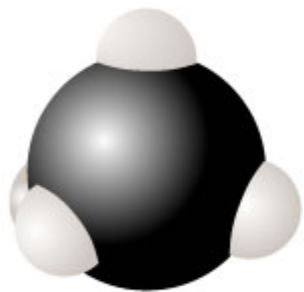
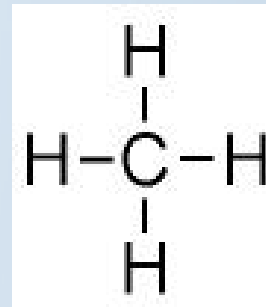
# Tetrahedral Geometry



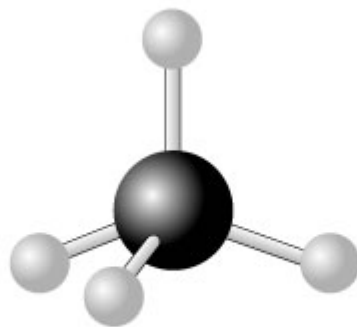
The blue shape is a regular tetrahedron.



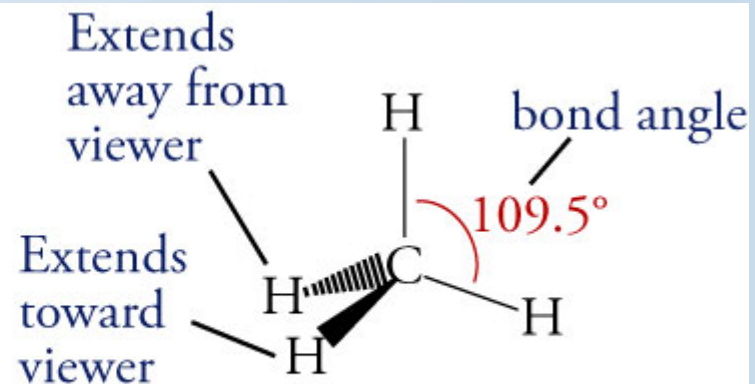
# Methane, CH<sub>4</sub>



Space-filling model



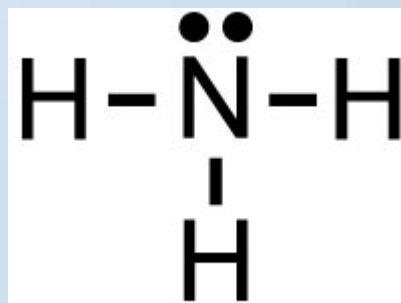
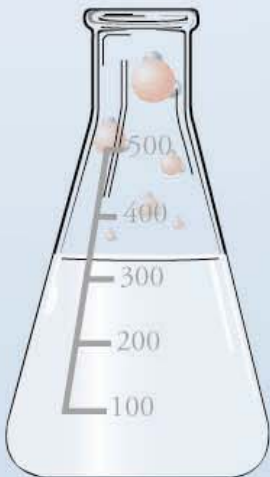
Ball-and-stick model



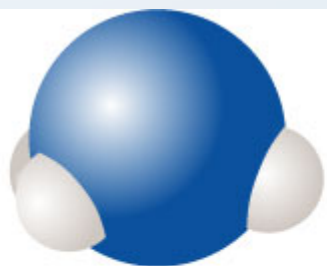
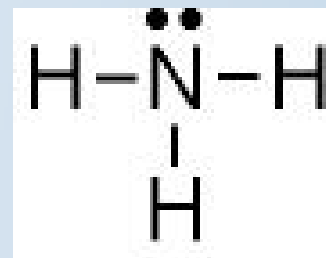
Geometric Sketch

# Lewis Structure for Ammonia, NH<sub>3</sub>

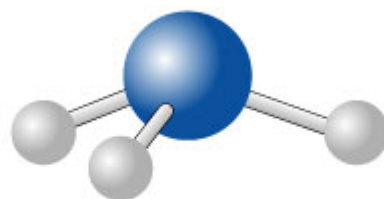
- Nitrogen atoms usually have 3 bonds and 1 lone pair.
- Hydrogen atoms have 1 bond and no lone pairs.



# Ammonia, NH<sub>3</sub>



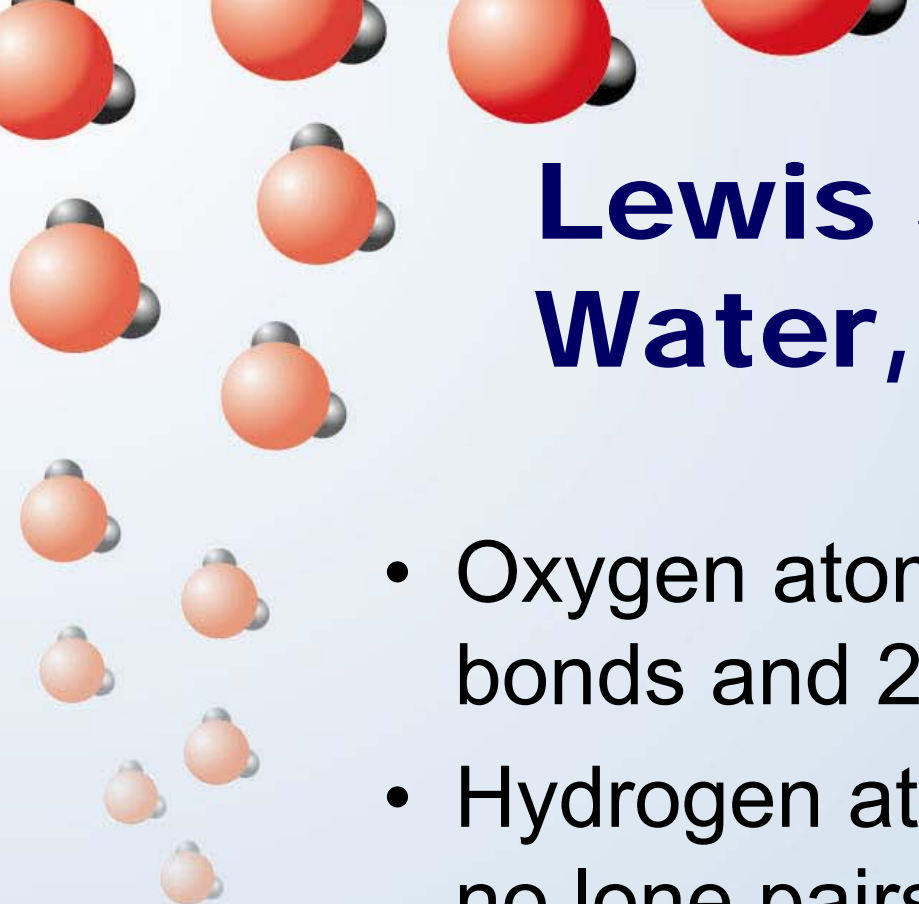
Space-filling model



Ball-and-stick model

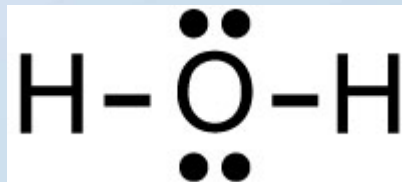
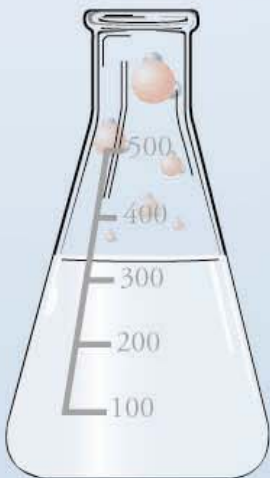


Geometric sketch

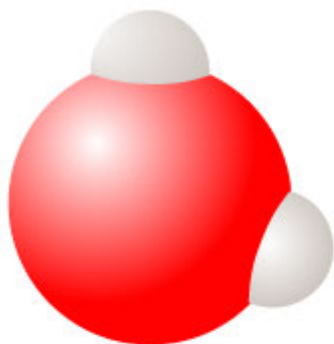
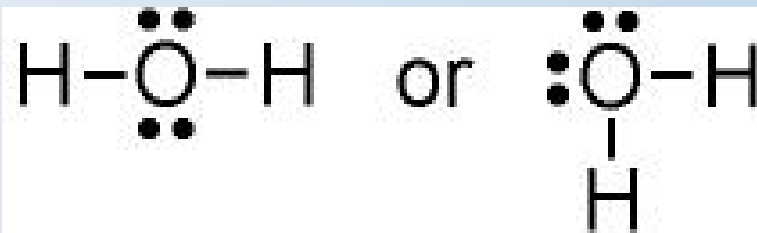
A decorative background on the left side of the slide features several water molecules. Each molecule is represented by a large red sphere (oxygen) and two smaller black spheres (hydrogen) arranged in a bent shape. The molecules are scattered across the upper and middle portions of the left side.

# Lewis Structure for Water, H<sub>2</sub>O

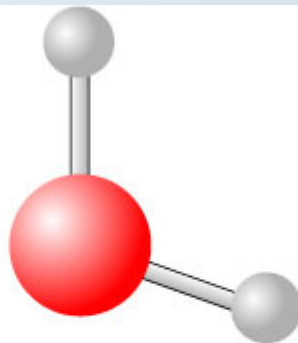
- Oxygen atoms usually have 2 bonds and 2 lone pairs.
- Hydrogen atoms have 1 bond and no lone pairs.



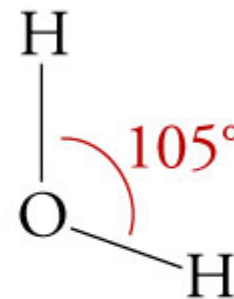
Water, H<sub>2</sub>O



Space-filling model



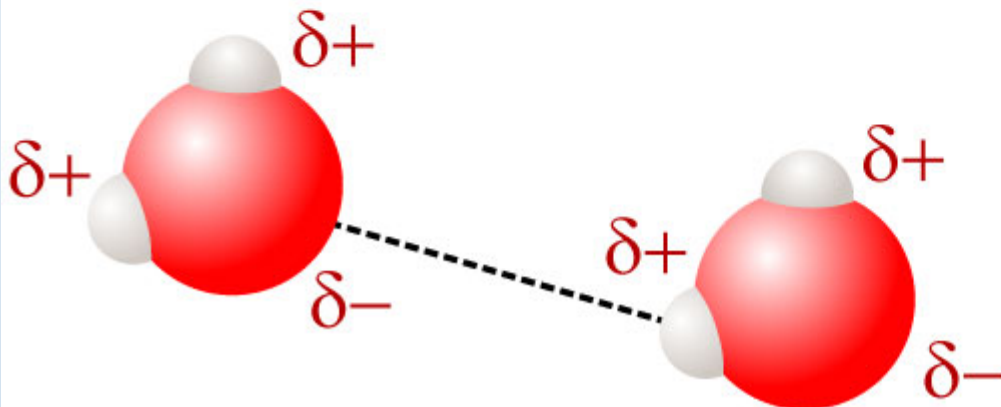
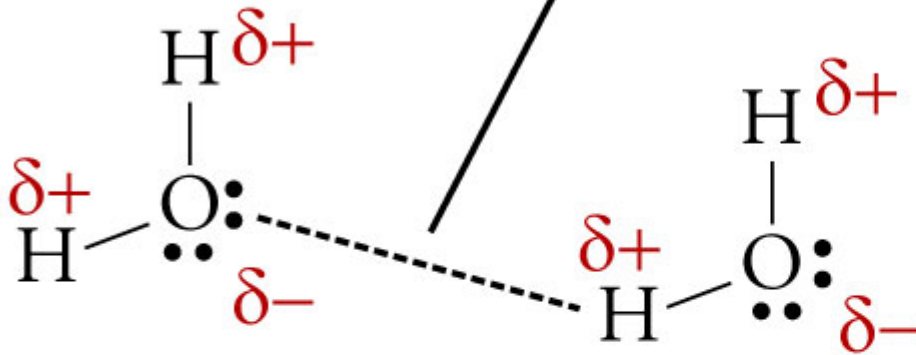
Ball-and-stick model



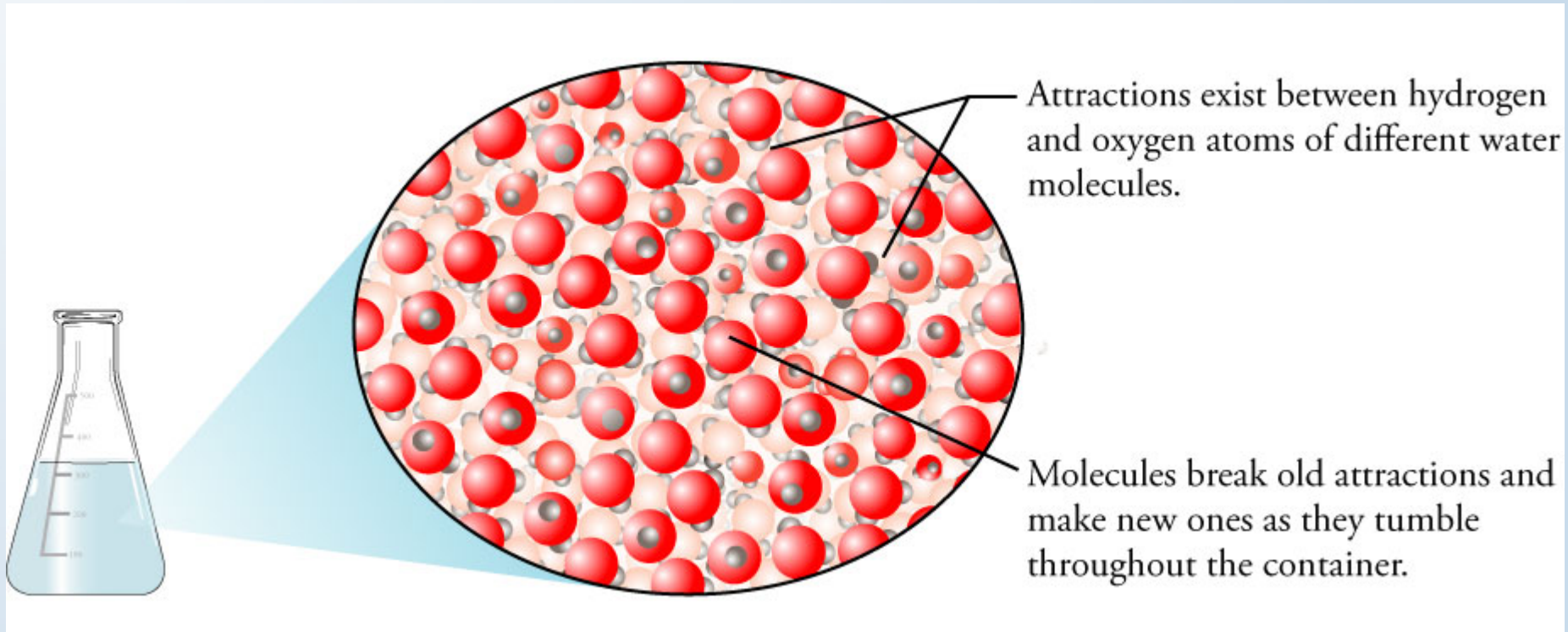
Geometric Sketch

# Water Attractions

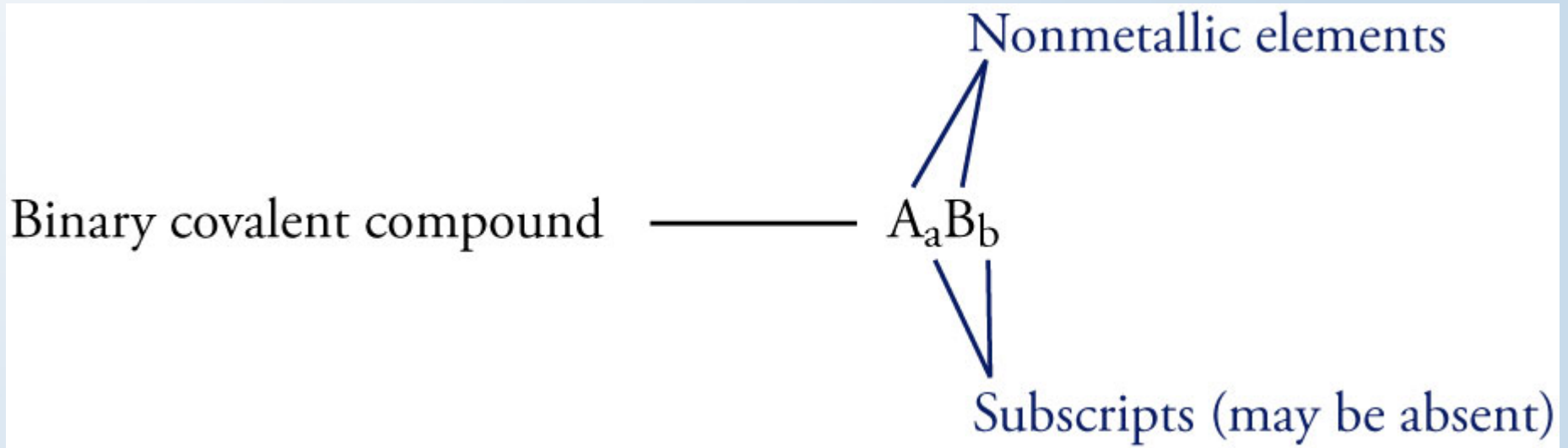
Attraction between partial positive charge and partial negative charge



# Liquid Water



# Binary Covalent





The image shows a series of ball-and-stick models of water molecules (H<sub>2</sub>O) arranged in a vertical column on the left side of the slide. Each molecule consists of one red sphere (oxygen) and two black spheres (hydrogen). The molecules appear to be rising from a flask at the bottom left. The flask is a standard Erlenmeyer flask with a scale on its side, ranging from 100 to 500. The scale has major markings at 100, 200, 300, 400, and 500. The flask is partially filled with a liquid, and several water molecules are shown rising from the surface of the liquid. The background is a light blue gradient.

# Common Names

–H<sub>2</sub>O, water

–NH<sub>3</sub>, ammonia

–CH<sub>4</sub>, methane

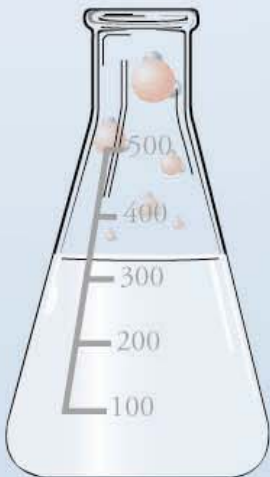
–C<sub>2</sub>H<sub>6</sub>, ethane

–C<sub>3</sub>H<sub>8</sub>, propane



# Naming Binary Covalent Compounds

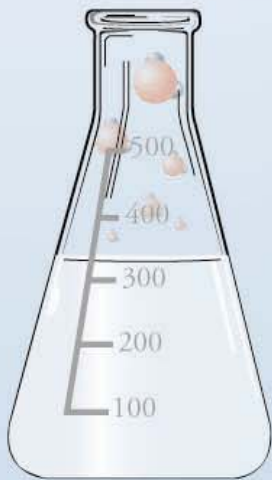
- If the subscript for the first element is greater than one, indicate the subscript with a prefix.
  - We do not write mono- on the first name.
  - Leave the "a" off the end of the prefixes that end in "a" and the "o" off of mono- if they are placed in front of an element that begins with a vowel (oxygen or iodine).
- Follow the prefix with the name of the first element in the formula.





# Naming Binary Covalent Compounds

- Write a prefix to indicate the subscript for the second element.
- Write the root of the name of the second symbol in the formula.
- Add -ide to the end of the name.



A vertical column of water molecules (H<sub>2</sub>O) is shown on the left side of the slide. Each molecule consists of one large red sphere (oxygen) and two smaller black spheres (hydrogen) bonded to it. The molecules are arranged in a descending staircase pattern from the top left towards the bottom left.

# Prefixes

mon(o)

di

tri

tetr(a)

pent(a)

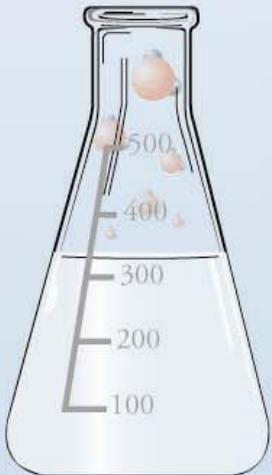
hex(a)

hept(a)

oct(a)

non(a)

dec(a)



# Roots of Nonmetals

H hydr-

C carb-

N nitr-

P phosph-

O ox-

S sulf-

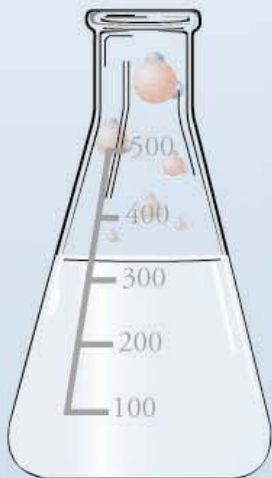
Se selen-

F fluor-

Cl chlor-

Br brom-

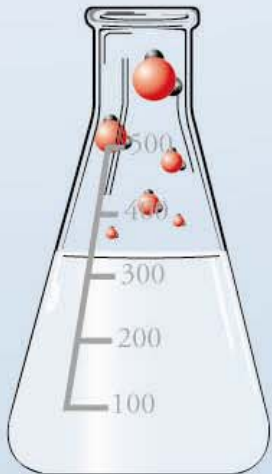
I iod-





# Forms of Binary Covalent Names

- prefix(name of nonmetal) prefix(root of name of nonmetal)ide
  - (for example, dinitrogen pentoxide)
- or (name of nonmetal) prefix(root of name of nonmetal)ide
  - (for example, carbon dioxide)
- or (name of nonmetal) (root of nonmetal)ide
  - (for example, hydrogen fluoride)



A decorative graphic on the left side of the slide shows several water molecules (one large orange sphere for oxygen and two smaller grey spheres for hydrogen) falling from the top left towards a flask at the bottom left. The flask is a conical flask with a scale on its side, marked with 100, 200, 300, 400, and 500. The flask is partially filled with a liquid, and several water molecules are shown inside it.

# Writing Binary Covalent Formulas

- Write the symbols for the elements in the order mentioned in the name.
- Write subscripts indicated by the prefixes. If the first part of the name has no prefix, assume it is mono-.

# The Making of an Anion

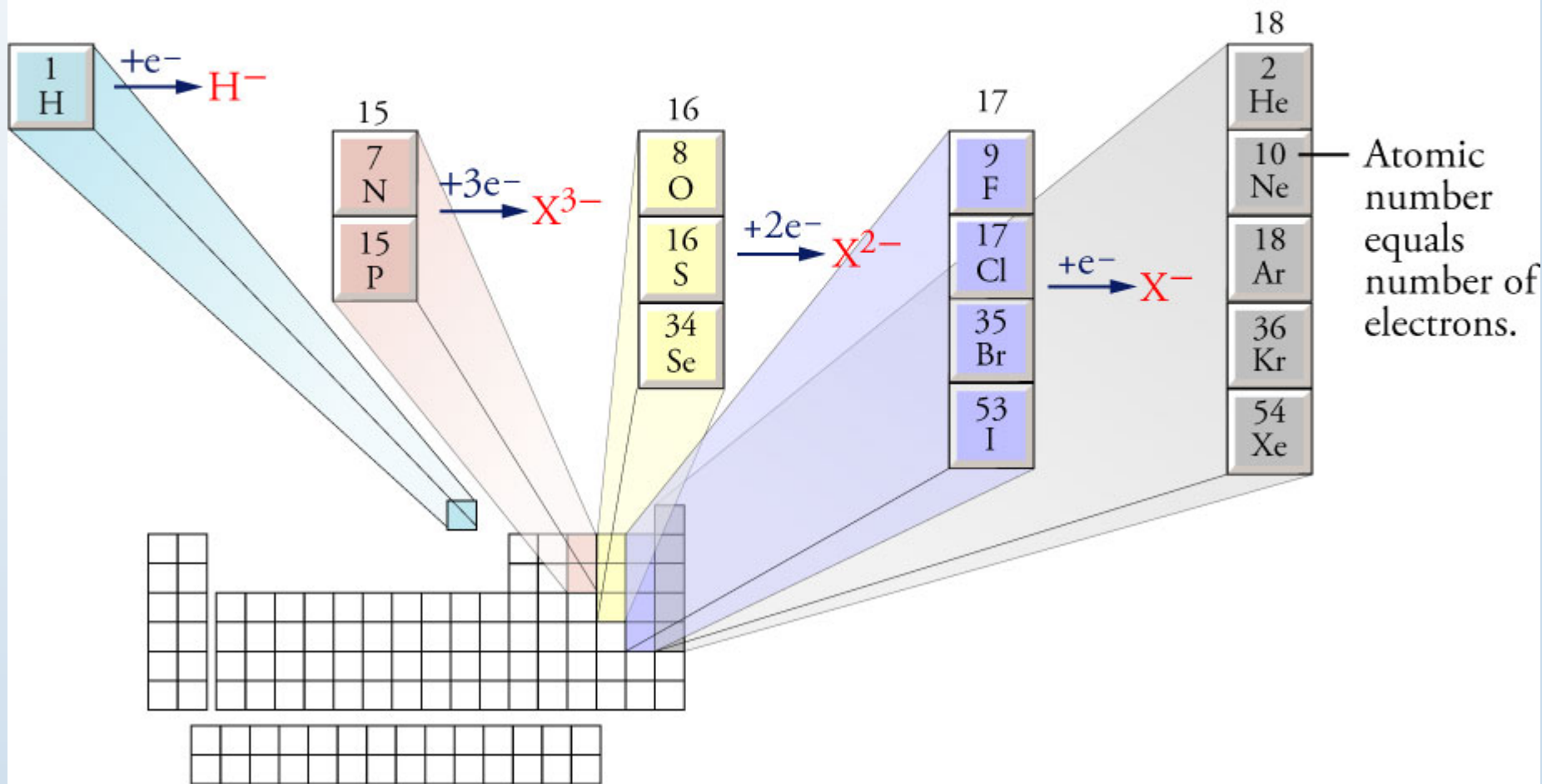
When a hydrogen atom gains 1 electron,

or when an atom in group 15 gains 3 electrons,

or when an atom in group 16 gains 2 electrons,

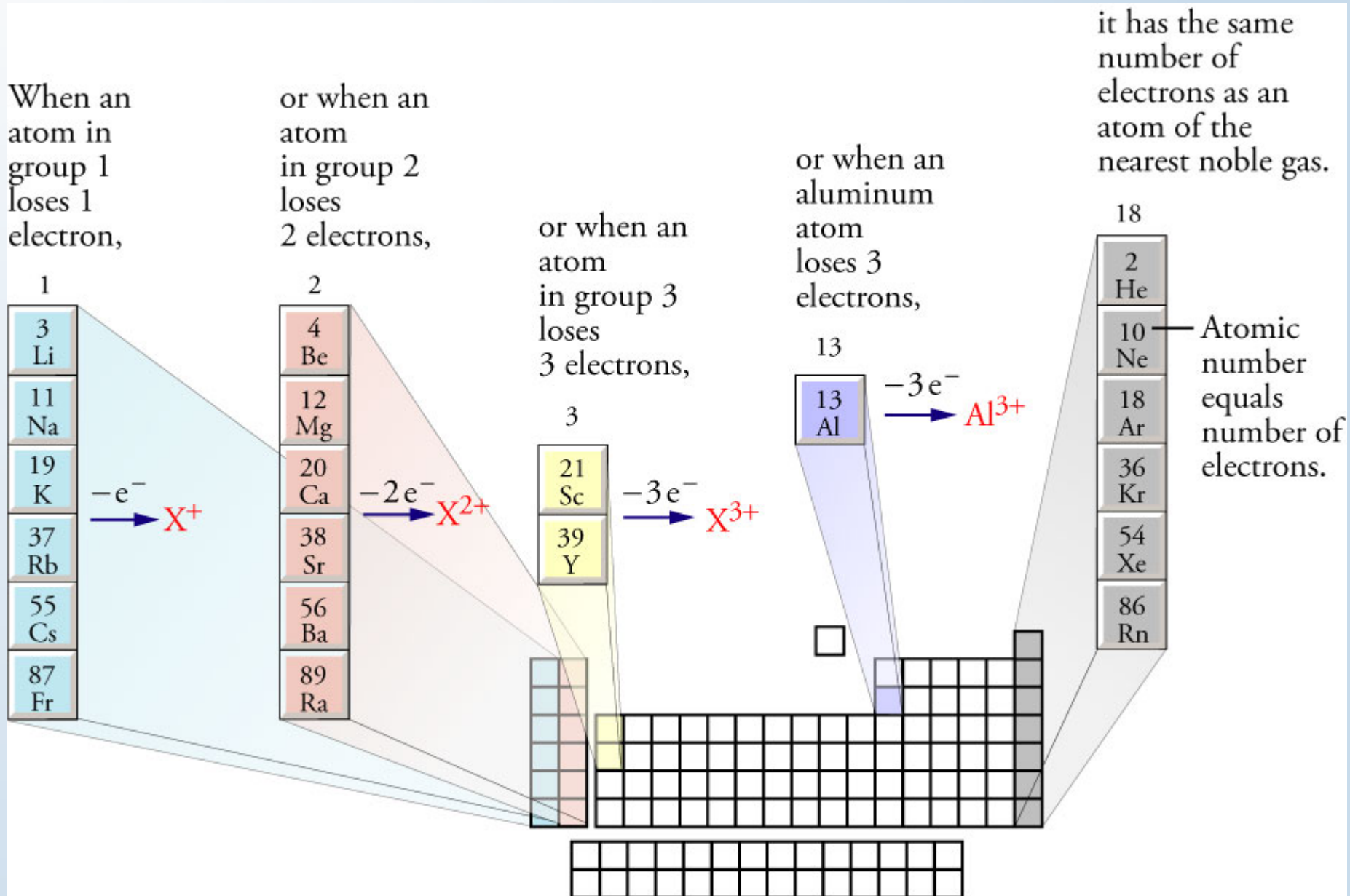
or when an atom in group 17 gains 1 electron,

it has the same number of electrons as an atom of the nearest noble gas.





# The Making of a Cation



# Monatomic Ions

1 1A	2 2A											13 3A	14 4A	15 5A	16 6A	17 7A	18 8A
Li <sup>+</sup>	Be <sup>2+</sup>													N <sup>3-</sup>	O <sup>2-</sup>	F <sup>-</sup>	
Na <sup>+</sup>	Mg <sup>2+</sup>	3 3B	4 4B	5 5B	6 6B	7 7B	8 8B	9 8B	10 8B	11 1B	12 2B	Al <sup>3+</sup>		p <sup>3-</sup>	S <sup>2-</sup>	Cl <sup>-</sup>	
K <sup>+</sup>	Ca <sup>2+</sup>	Sc <sup>3+</sup>					Fe <sup>2+</sup> Fe <sup>3+</sup>			Cu <sup>+</sup> Cu <sup>2+</sup>	Zn <sup>2+</sup>				Se <sup>2-</sup>	Br <sup>-</sup>	
Rb <sup>+</sup>	Sr <sup>2+</sup>	Y <sup>3+</sup>								Ag <sup>+</sup>	Cd <sup>2+</sup>					I <sup>-</sup>	
Cs <sup>+</sup>	Ba <sup>2+</sup>																
Fr <sup>+</sup>	Ra <sup>2+</sup>																

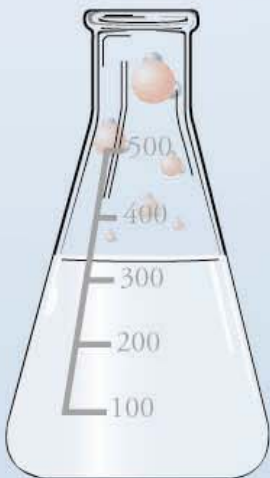
  

H <sup>-</sup>
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# Monatomic Ion Names

- Monatomic Cations
  - (name of metal)
    - Groups 1, 2, and 3 metals
    - $\text{Al}^{3+}$ ,  $\text{Zn}^{2+}$ ,  $\text{Cd}^{2+}$ ,  $\text{Ag}^{+}$
  - (name of metal)(Roman numeral)
    - All metallic cations not mentioned above
- Monatomic Anions
  - (root of nonmetal name)ide



# Monatomic Anions

Hydride  $\text{H}^-$

Nitride  $\text{N}^{3-}$

Phosphide  $\text{P}^{3-}$

Oxide  $\text{O}^{2-}$

Sulfide  $\text{S}^{2-}$

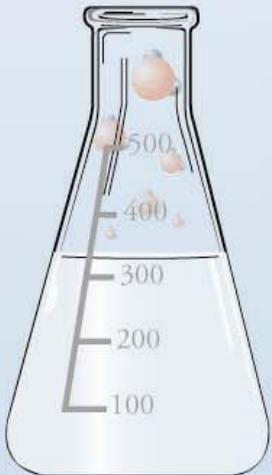
selenide  $\text{Se}^{2-}$

fluoride  $\text{F}^-$

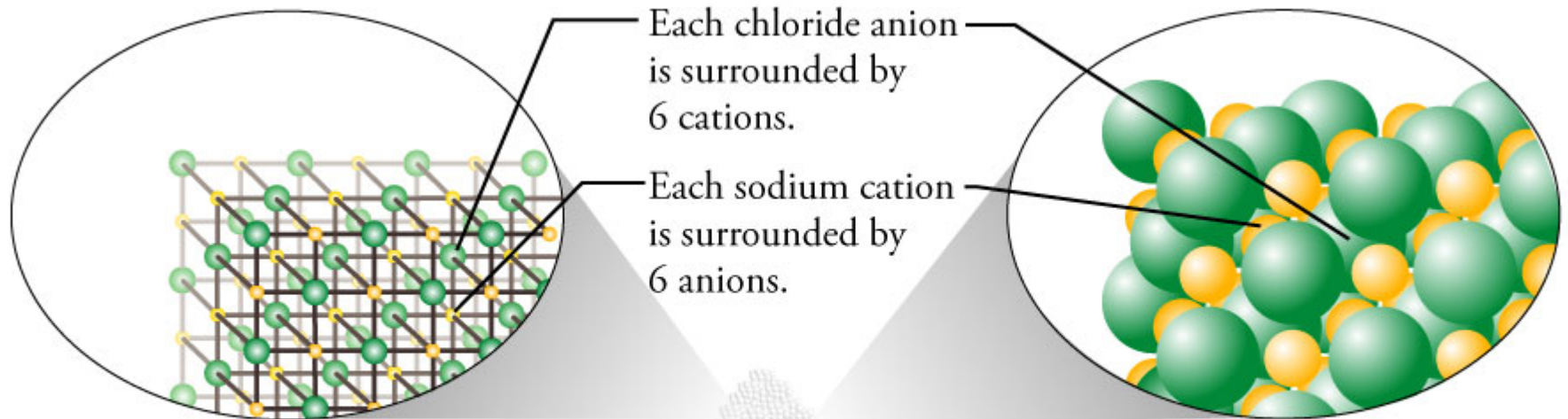
chloride  $\text{Cl}^-$

bromide  $\text{Br}^-$

iodide  $\text{I}^-$



# Sodium Chloride, NaCl, Structure

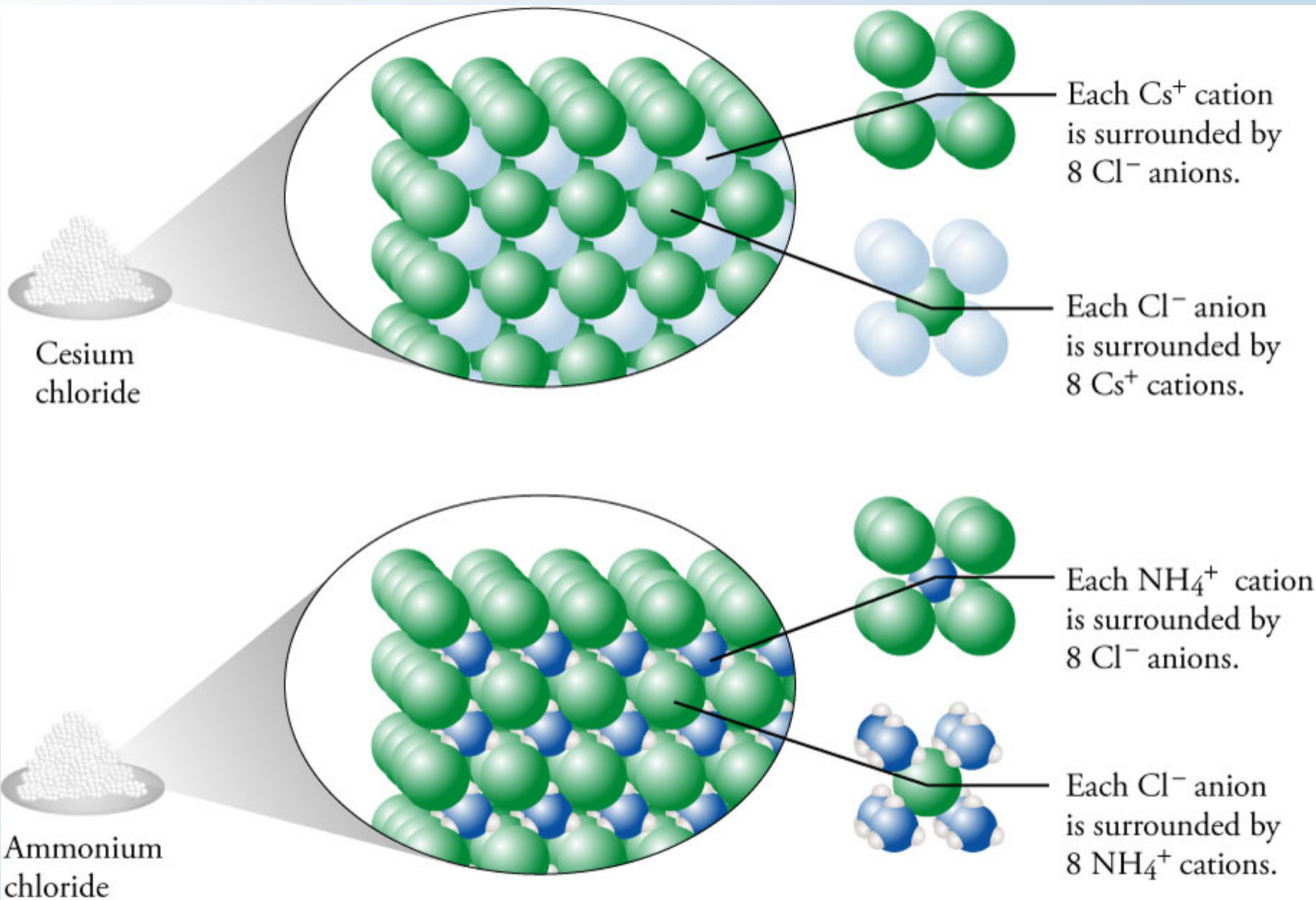


Ball-and-stick model

Salt (sodium chloride)

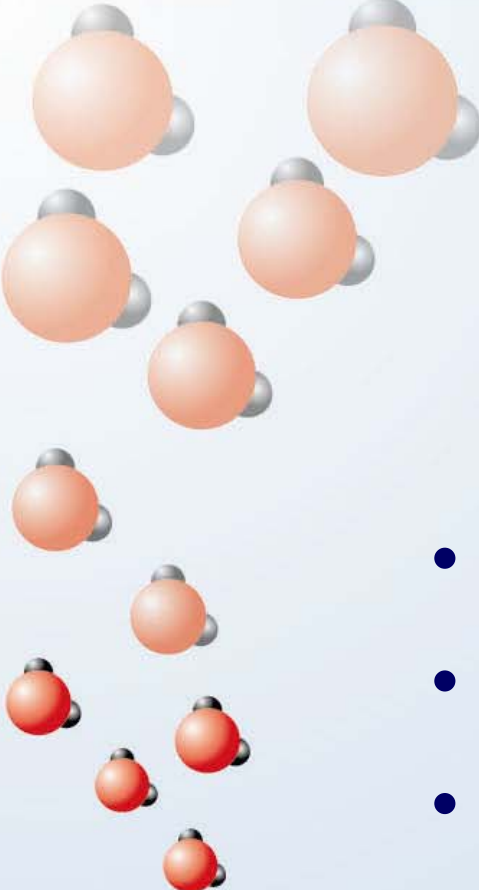
Space-filling model

# CsCl and NH<sub>4</sub>Cl structure



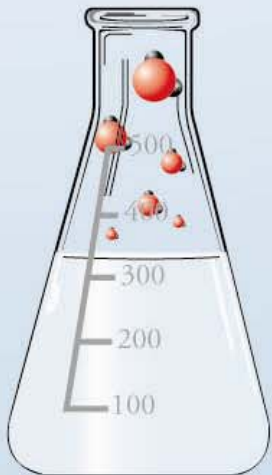
# Polyatomic Ions

Ion	Name	Ion	Name
$\text{NH}_4^+$	ammonium	$\text{NO}_3^-$	nitrate
$\text{OH}^-$	hydroxide	$\text{SO}_4^{2-}$	sulfate
$\text{CO}_3^{2-}$	carbonate	$\text{C}_2\text{H}_3\text{O}_2^-$	acetate
$\text{PO}_4^{3-}$	phosphate		

A series of ball-and-stick molecular models for polyatomic ions with hydrogen, arranged in a descending staircase pattern from the top left. The models include carbonate (CO3), bicarbonate (HCO3), sulfate (SO4), bisulfate (HSO4), sulfide (HS), phosphate (PO4), and dihydrogen phosphate (H2PO4). Each model consists of a central atom (orange for carbon, red for sulfur, grey for phosphorus) bonded to oxygen (red) and hydrogen (white) atoms.

# Polyatomic Ions with Hydrogen

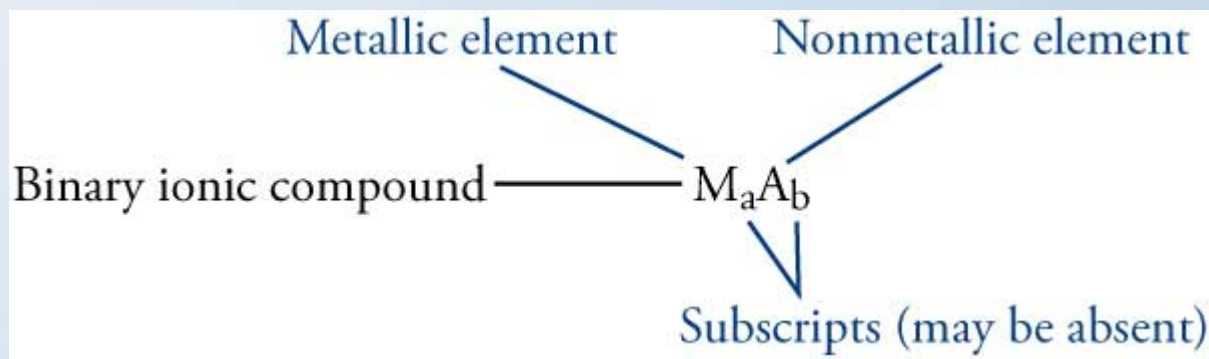
- $\text{HCO}_3^-$  hydrogen carbonate
- $\text{HSO}_4^-$  hydrogen sulfate
- $\text{HS}^-$  hydrogen sulfide
- $\text{HPO}_4^{2-}$  hydrogen phosphate
- $\text{H}_2\text{PO}_4^-$  dihydrogen phosphate



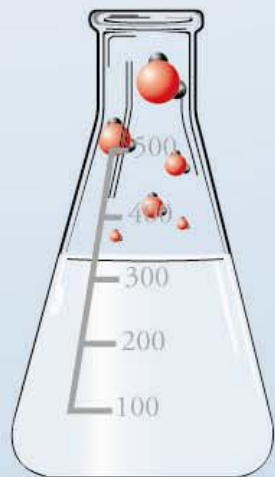


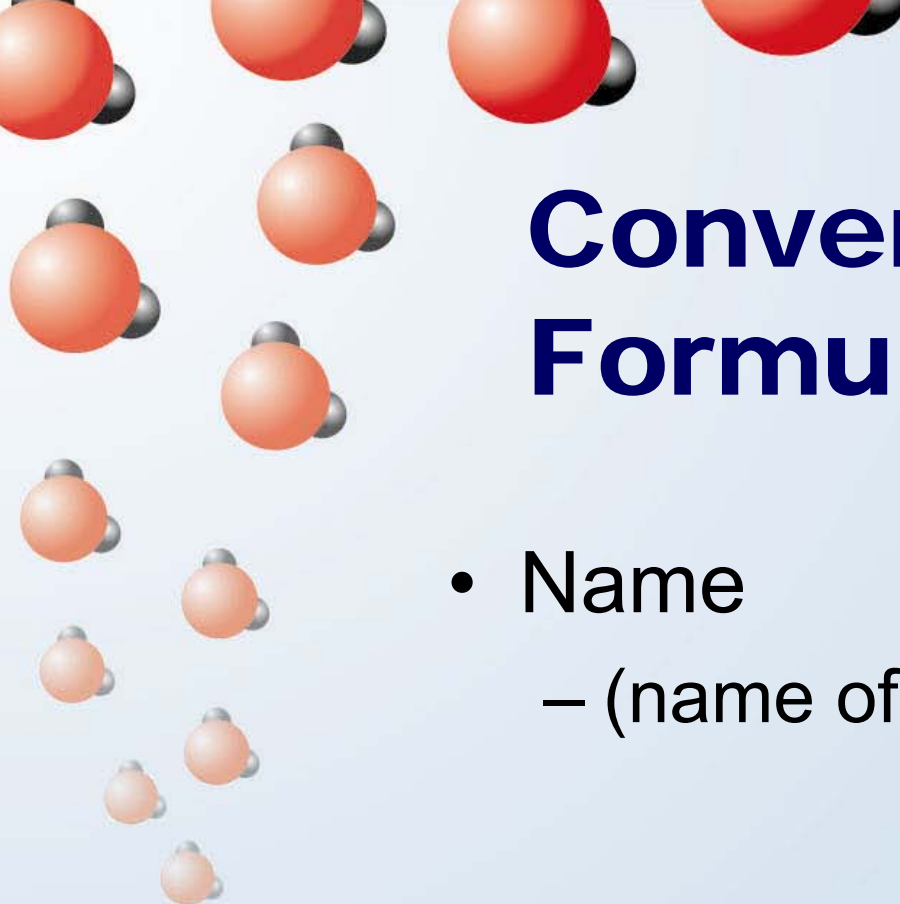
# Recognizing Ionic Compounds

- Metal-nonmetal...binary ionic compound



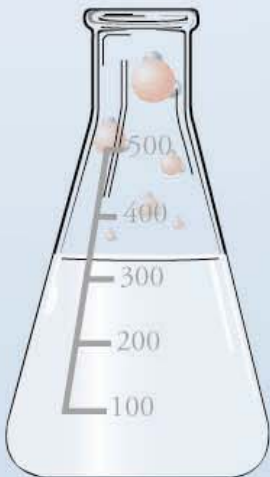
- Metal-polyatomic ion
- Ammonium-nonmetal or ammonium polyatomic ion



A decorative vertical column of water molecules (H<sub>2</sub>O) on the left side of the slide. Each molecule consists of one red oxygen atom and two white hydrogen atoms. The molecules are arranged in a descending staircase pattern from the top left towards the bottom left.

# Converting Ionic Formulas to Names

- Name
  - (name of cation) (name of anion)



# Cation Names

Metals with one possible charge (Al, Zn, Cd, and Groups 1, 2, 3)	name of metal
Metals with more than one possible charge (the rest)	name(Roman numeral)
polyatomic cations (e.g. ammonium)	name of polyatomic ion

# Anion Names

monatomic anion	(root of nonmetal name)ide
polyatomic anion	name of polyatomic ion



# Converting Ionic Names to Formulas

- Determine the formula, including charge, for the cation and anion.
- Determine the ratio of the ions that yields zero overall charge.

