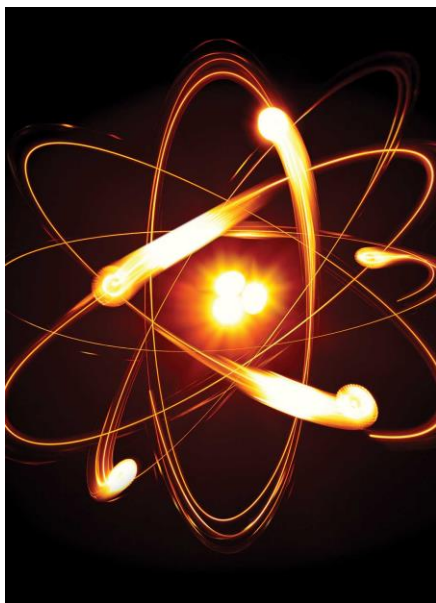


# Atoms, Molecules, and Ions



zoom-zoom/Getty Images

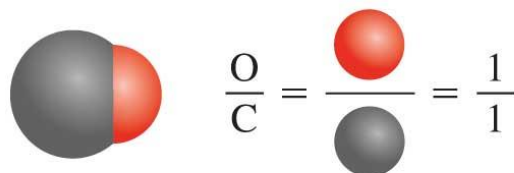
## *Chapter 2*

# Dalton's Atomic Theory (1808)

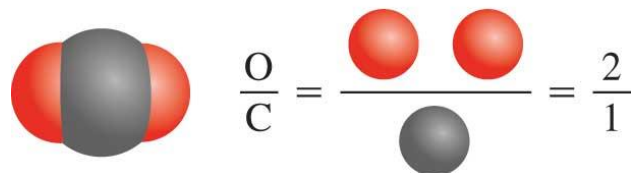
1. Elements are composed of extremely small particles called ***atoms***.
2. All ***atoms*** of a given element are identical, having the same size, mass and chemical properties. The atoms of one element are different from the atoms of all other elements.
3. ***Compounds*** are composed of atoms of more than one element. In any compound, the ratio of the numbers of atoms of any two of the elements present is either an integer or a simple fraction.
4. A ***chemical reaction*** involves only the separation, combination, or rearrangement of atoms; it does not result in their creation or destruction.

# Dalton's Atomic Theory

Carbon monoxide



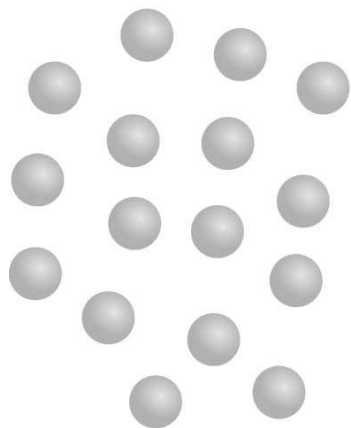
Carbon dioxide



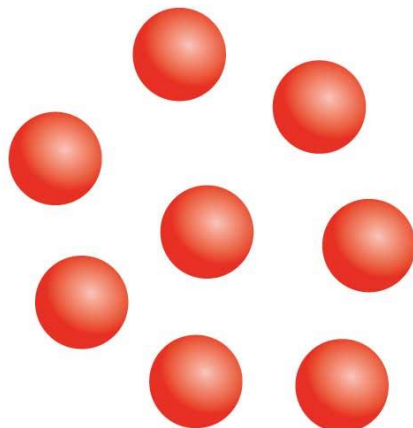
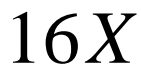
## Law of Multiple Proportions

[Access the text alternative for slide images.](#)

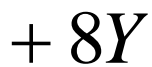
# Law of Conservation of Mass



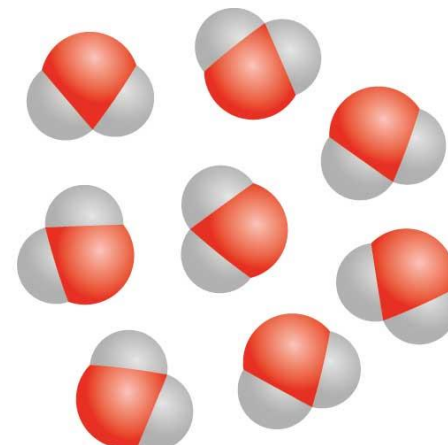
Atoms of element X



Atoms of element Y

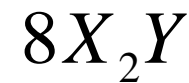


(a)



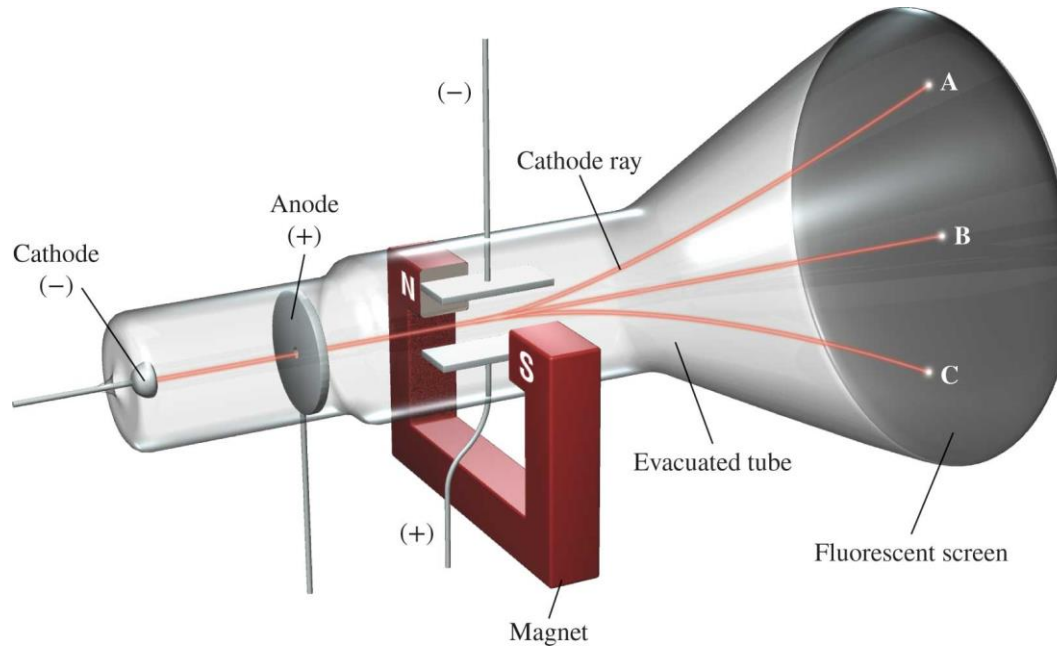
Compounds of elements X and Y

(b)



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# Cathode Ray Tube 1

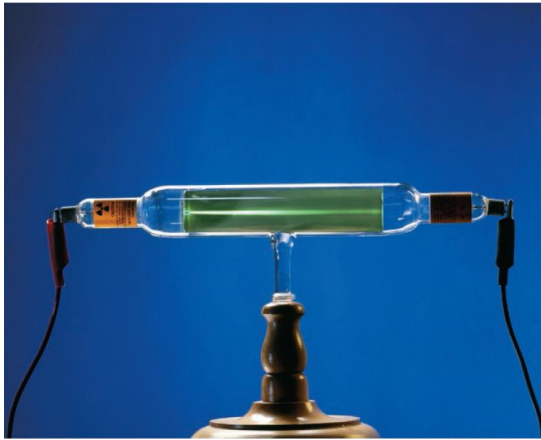


J.J. Thomson, **measured mass/charge of  $e^-$**

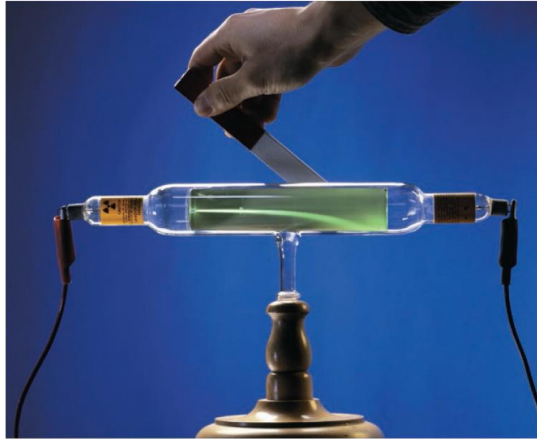
(1906 Nobel Prize in Physics)

[Access the text alternative for slide images.](#)

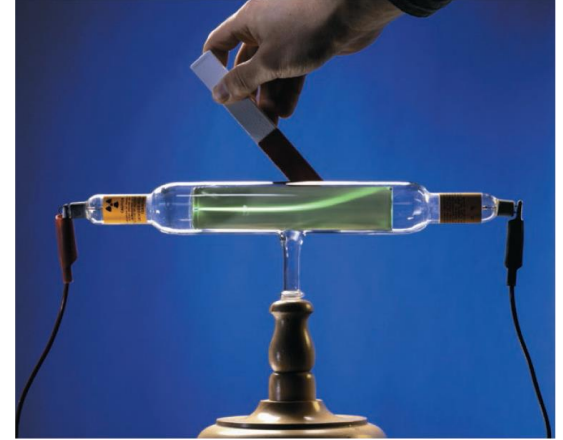
# Cathode Ray Tube 2



(a)



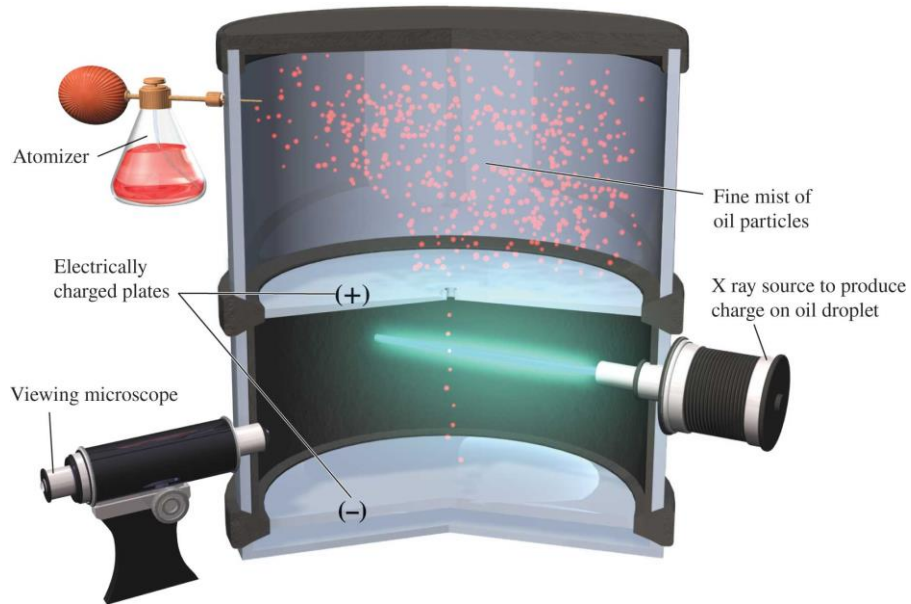
(b)



(c)

[Access the text alternative for slide images.](#)

# Millikan's Experiment



**Measured mass of  $e^-$**   
(1923 Nobel Prize in Physics)

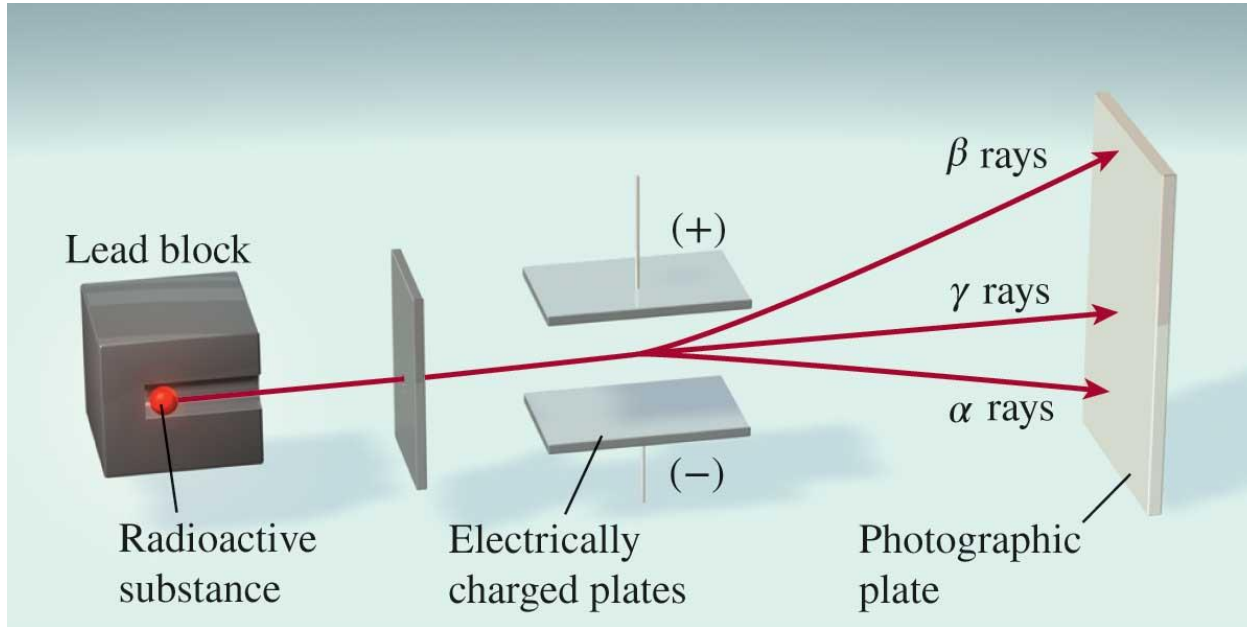
$$e^- \text{ charge} = -1.60 \times 10^{-19} \text{ C}$$

$$\text{Thompson's charge/mass of } e^- = -1.76 \times 10^8 \text{ C/g}$$

$$e^- \text{ mass} = 9.10 \times 10^{-28} \text{ g}$$

[Access the text alternative for slide images.](#)

# Types of Radioactivity



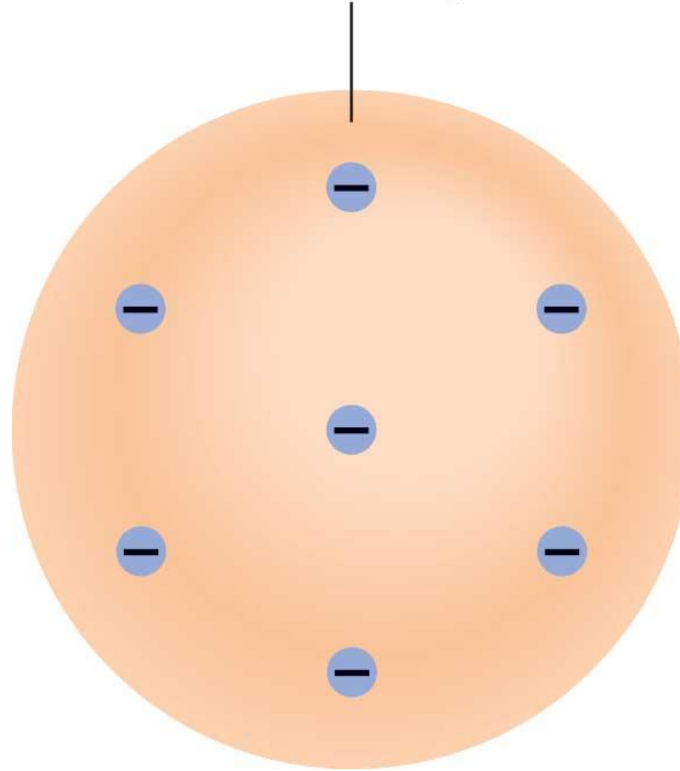
(uranium compound)

[Access the text alternative for slide images.](#)



# Thomson's Model

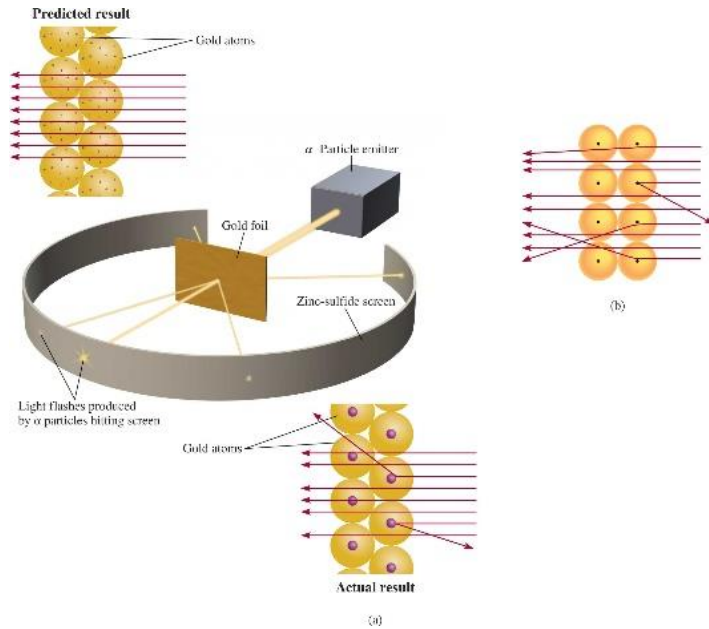
Positive charge spread  
over the entire sphere



[Access the text alternative for slide images.](#)

# Rutherford's Experiment

(1908 Nobel Prize in Chemistry)

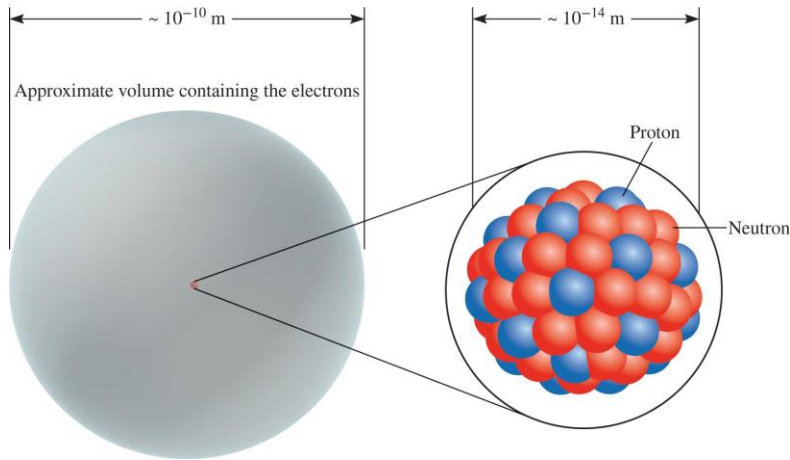


$\alpha$  particle velocity  $\sim 1.4 \times 10^7$  m/s  
(  $\sim 5\%$  speed of light )

1. atoms positive charge is concentrated in the nucleus
2. proton (p) has opposite (+) charge of electron (-)
3. mass of p is  $1840 \times$  mass of  $e^-$  ( $1.67 \times 10^{-24}$  g)

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# Rutherford's Model of the Atom



atomic radius  $\sim 100 \text{ pm} = 1 \times 10^{-10} \text{ m}$

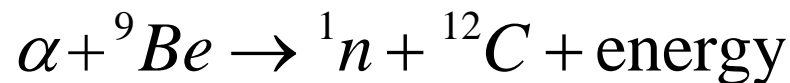
nuclear radius  $\sim 5 \times 10^{-3} \text{ pm} = 5 \times 10^{-15} \text{ m}$



*“If the size of an atom were expanded to that of this sports stadium, the size of the nucleus would be that of a marble.”*

# Chadwick's Experiment (1932) (1935 Noble Prize in Physics)

H atoms: 1 p; He atoms: 2 p  
mass He/mass H should = 2  
measured mass He/mass H = 4



**neutron (n) is neutral (charge = 0)**

n mass  $\square$  p mass =  $1.67 \times 10^{-24}$  g

# Properties of Subatomic Particles

**TABLE 2.1** Mass and Charge of Subatomic Particles

Particle	Mass (g)	Charge	
		Coulomb	Charge Unit
Electron*	$9.10938 \times 10^{-28}$	$-1.6022 \times 10^{-19}$	-1
Proton	$1.67262 \times 10^{-24}$	$+1.6022 \times 10^{-19}$	+1
Neutron	$1.67493 \times 10^{-24}$	0	0

\*More refined measurements have given us a more accurate value of an electron's mass than Millikan's.

**mass p  $\approx$  mass n  $\approx$  1840 x mass e<sup>-</sup>**

[Access the text alternative for slide images.](#)

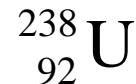
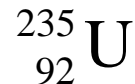
# Atomic Number, Mass Number, and Isotopes

**Atomic number** ( $Z$ ) = number of protons in nucleus

**Mass number** ( $A$ ) = number of protons + number of neutrons  
= atomic number ( $Z$ ) + number of neutrons

**Isotopes** are atoms of the same element ( $X$ ) with different numbers of neutrons in their nuclei

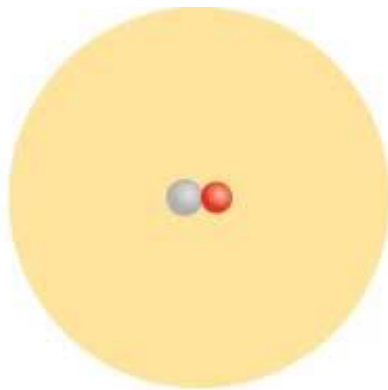
Mass Number  $\rightarrow$   $A$   $X$   $\leftarrow$  Element Symbol  
Atomic Number  $\rightarrow$   $Z$



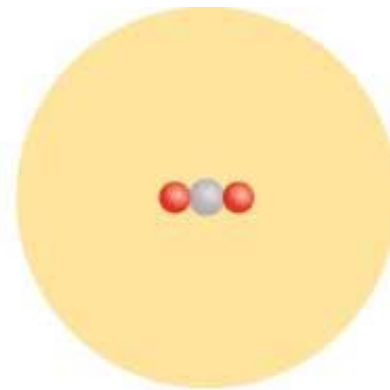
# The Isotopes of Hydrogen



**hydrogen**



**deuterium**



**tritium**

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# Atomic number, Mass number and Isotopes

**Atoms are electrically neutral; the number of electrons is equal to the number of protons.**

How many protons, neutrons, and electrons are in  ${}^{14}_6\text{C}$  ?

6 protons, 8 (14- 6) neutrons, 6 electrons

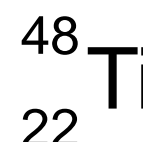
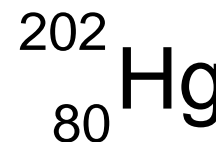
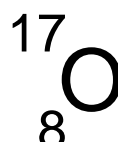
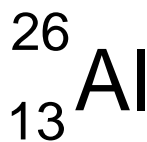
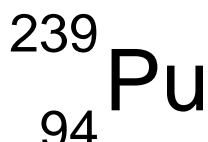
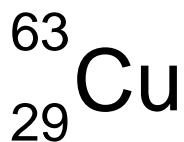
How many protons, neutrons, and electrons are in  ${}^{11}_6\text{C}$  ?

6 protons, 5 (11 - 6) neutrons, 6 electrons



# Atomic number, Mass number and Isotopes

Find number of electrons, protons, and neutrons?



<b>e<sup>-</sup></b>	29	94	13	8	80	22
<b>p<sup>+</sup></b>	29	94	13	8	80	22
<b>n</b>	34	145	13	9	122	26

## EXAMPLE 2.1

Give the number of protons, neutrons, and electrons in each of the following species: (a)  ${}^{20}_{11}\text{Na}$ , (b)  ${}^{22}_{11}\text{Na}$ , (c)  ${}^{17}\text{O}$ , and (d) carbon-14.

- Solution** (a) The atomic number is 11, so there are 11 protons. The mass number is 20, so the number of neutrons is  $20 - 11 = 9$ . The number of electrons is the same as the number of protons; that is, 11.
- (b) The atomic number is the same as that in (a), or 11. The mass number is 22, so the number of neutrons is  $22 - 11 = 11$ . The number of electrons is 11. Note that the species in (a) and (b) are chemically similar isotopes of sodium.
- (c) The atomic number of O (oxygen) is 8, so there are 8 protons. The mass number is 17, so there are  $17 - 8 = 9$  neutrons. There are 8 electrons.
- (d) Carbon-14 can also be represented as  ${}^{14}\text{C}$ . The atomic number of carbon is 6, so there are  $14 - 6 = 8$  neutrons. The number of electrons is 6.

# The Modern Periodic Table

1 1A											13 3A	14 4A	15 5A	16 6A	17 7A	18 8A	
1 H											5 B	6 C	7 N	8 O	9 F	10 Ne	
3 Li	4 Be	3 3B	4 4B	5 5B	6 6B	7 7B	8 8B	9 8B	10 8B	11 1B	12 2B	13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
55 Cs	56 Ba	57 La	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
87 Fr	88 Ra	89 Ac	104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Ds	111 Rg	112	113	114	115	116	(117)	118

Period →

Group ↓

Alkali Metal

Alkali Earth Metal

Halogen

Noble Gas

Metals
Metalloids
Nonmetals

58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb	71 Lu
90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No	103 Lr

1/2 of elements discovered between (1800-1900)

Only noble gases exist as single atoms called **monoatomic**

**Period** : increasing Z

Metals → Metalloids → Nonmetals

**Group** : similar chemical properties

**Metals**

- good conductors of heat and electricity
- occupy most of the table

**Nonmetals**

- not good conductors of heat and electricity
- only 17 elements

**Metalloids**

- Intermediate between metals and nonmetals
- only 8 elements

# Molecules

A ***molecule*** is an aggregate of two or more atoms in a definite arrangement held together by chemical forces.

A ***diatomic molecule*** contains only two atoms:



1	2																18
														N	O	F	
																Cl	
																Br	
																I	

diatomic elements

A ***polyatomic molecule*** contains more than two atoms:



# Ions

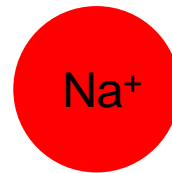
An **ion** is an atom, or group of atoms, that has a net positive or negative charge.

**cation** – ion with a positive charge

If a neutral atom **loses** one or more electrons it becomes a cation.



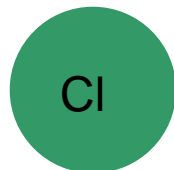
11 protons  
11 electrons



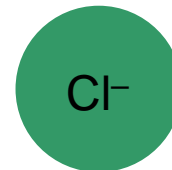
11 protons  
10 electrons

**anion** – ion with a negative charge

If a neutral atom **gains** one or more electrons it becomes an anion.



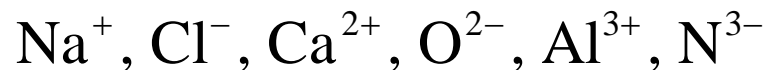
17 protons  
17 electrons



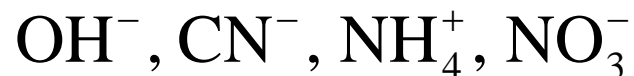
17 protons  
18 electrons

# Types of Ions

A *monatomic ion* contains only one atom:



A *polyatomic ion* contains more than one atom:



How many protons and electrons are in  ${}_{13}^{27}\text{Al}^{3+}$ ?

13 protons, 10 (13 – 3) electrons

How many protons and electrons are in  ${}_{34}^{78}\text{Se}^{2-}$ ?

34 protons, 36 (34 + 2) electrons



# Common Ions Shown on the Periodic Table

1 1A	2 2A											13 3A	14 4A	15 5A	16 6A	17 7A	18 8A	
Li <sup>+</sup>														C <sup>4-</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		10	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>				Cr <sup>2+</sup> Cr <sup>3+</sup>	Mn <sup>2+</sup> Mn <sup>3+</sup>	Fe <sup>2+</sup> Fe <sup>3+</sup>	Co <sup>2+</sup> Co <sup>3+</sup>	Ni <sup>2+</sup> Ni <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>									Ag <sup>+</sup>	Cd <sup>2+</sup>		Sn <sup>2+</sup> Sn <sup>4+</sup>		Te <sup>2-</sup>	I <sup>-</sup>		
Cs <sup>+</sup>	Ba <sup>2+</sup>									Au <sup>+</sup> Au <sup>3+</sup>	Hg <sub>2</sub> <sup>2+</sup> Hg <sup>2+</sup>		Pb <sup>2+</sup> Pb <sup>4+</sup>					

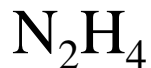
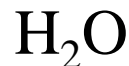
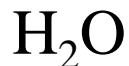
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# Types of Formulas



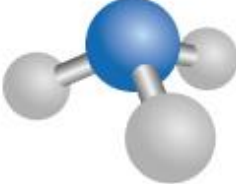
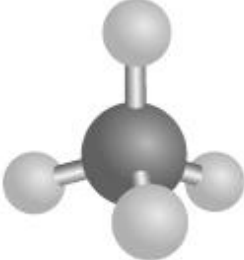



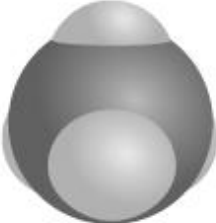
A ***molecular formula*** shows the exact number of atoms of each element in the smallest unit of a substance.

An ***empirical formula*** shows the simplest whole-number ratio of the atoms in a substance.

<u>molecular</u>	<u>empirical</u>
------------------	------------------



# Formulas and Models

	Hydrogen	Water	Ammonia	Methane
Molecular formula	$H_2$	$H_2O$	$NH_3$	$CH_4$
Structural formula	$H-H$	$H-O-H$	$\begin{array}{c} H-N-H \\   \\ H \end{array}$	$\begin{array}{c} H \\   \\ H-N-H \\   \\ H \end{array}$
Ball-and-stick model				
Space-filling model				

[Access the text alternative for slide images.](#)

## EXAMPLE 2.3

Write the empirical formulas for the following molecules: (a) acetylene ( $\text{C}_2\text{H}_2$ ), which is used in welding torches; (b) glucose ( $\text{C}_6\text{H}_{12}\text{O}_6$ ), a substance known as blood sugar; and (c) nitrous oxide ( $\text{N}_2\text{O}$ ), a gas that is used as an anesthetic gas (“laughing gas”) and as an aerosol propellant for whipped creams.

**Strategy** Recall that to write the empirical formula, the subscripts in the molecular formula must be converted to the smallest possible whole numbers.

### Solution

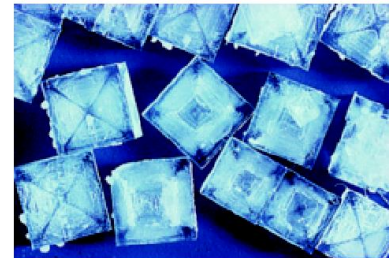
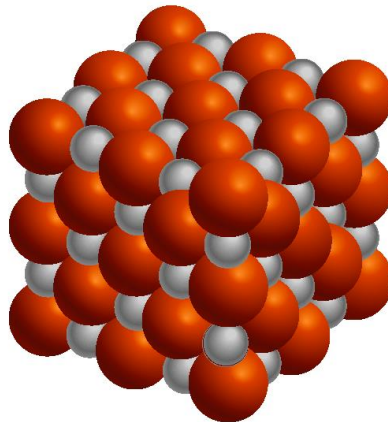
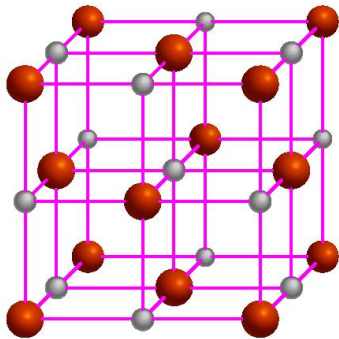
- (a) There are two carbon atoms and two hydrogen atoms in acetylene. Dividing the subscripts by 2, we obtain the empirical formula  $\text{CH}$ .
- (b) In glucose there are 6 carbon atoms, 12 hydrogen atoms, and 6 oxygen atoms. Dividing the subscripts by 6, we obtain the empirical formula  $\text{CH}_2\text{O}$ . Note that if we had divided the subscripts by 3, we would have obtained the formula  $\text{C}_2\text{H}_4\text{O}_2$ . Although the ratio of carbon to hydrogen to oxygen atoms in  $\text{C}_2\text{H}_4\text{O}_2$  is the same as that in  $\text{C}_6\text{H}_{12}\text{O}_6$  (1:2:1),  $\text{C}_2\text{H}_4\text{O}_2$  is not the simplest formula because its subscripts are not in the smallest whole-number ratio.
- (c) Because the subscripts in  $\text{N}_2\text{O}$  are already the smallest possible whole numbers, the empirical formula for nitrous oxide is the same as its molecular formula.

# Ionic Compounds

***Ionic compounds*** consist of a combination of cations and anions.

- The formula is usually the same as the empirical formula.
- The sum of the charges on the cation(s) and anion(s) in each formula unit must equal zero.

The ionic compound NaCl



# Reactive Elements

1A	2A										3A	4A	5A	6A	7A	8A
Li													N	O	F	
Na	Mg										Al			S	Cl	
K	Ca														Br	
Rb	Sr														I	
Cs	Ba															

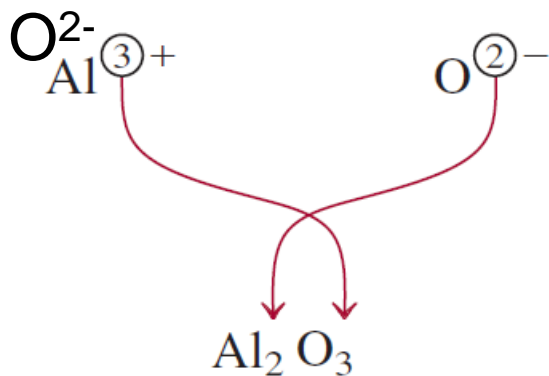
The most reactive **metals** (green) and the most reactive **nonmetals** (blue) combine to form **ionic compounds**.

# Formula of Ionic Compounds

If the charges on the cation and anion are numerically different, we apply the following rule to make the formula electrically neutral.

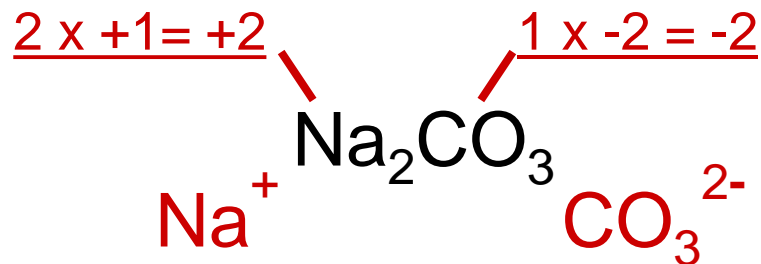
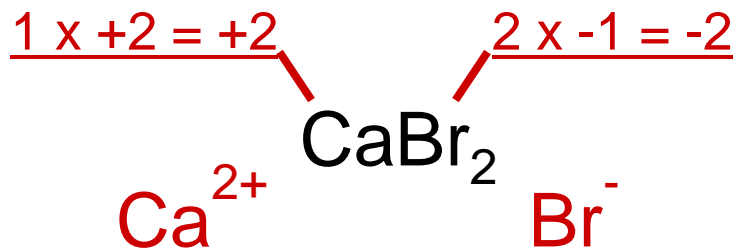
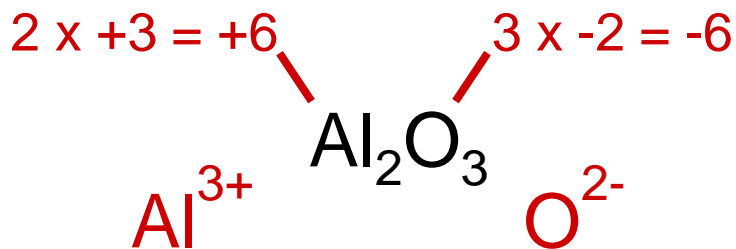
*The subscript of the cation is numerically equal to the charge on the anion, and the subscript of the anion is numerically equal to the charge on the cation.*

**Aluminum Oxide.** The cation is  $\text{Al}^{3+}$  and the oxygen anion is



The sum of the charges is  $2(+3) + 3(-2) = 0$   
Thus, the formula for aluminum oxide is  **$\text{Al}_2\text{O}_3$** .

# Formula of Ionic Compounds





# Chemical Nomenclature

## Ionic Compounds

- Often a metal + nonmetal
- Anion (nonmetal), add “-ide” to element name

$\text{BaCl}_2$       barium chloride

$\text{K}_2\text{O}$           potassium oxide

$\text{Mg}(\text{OH})_2$     magnesium hydroxide

$\text{KNO}_3$          potassium nitrate

# Naming Monatomic Anions

**TABLE 2.2** The “-ide” Nomenclature of Some Common Monatomic Anions According to Their Positions in the Periodic Table

Group 4A	Group 5A	Group 6A	Group 7A
C carbide ( $C^{4-}$ )*	N nitride ( $N^{3-}$ )	O oxide ( $O^{2-}$ )	F fluoride ( $F^{-}$ )
Si silicide ( $Si^{4-}$ )	P phosphide ( $P^{3-}$ )	S sulfide ( $S^{2-}$ )	Cl chloride ( $Cl^{-}$ )
		Se selenide ( $Se^{2-}$ )	Br bromide ( $Br^{-}$ )
		Te telluride ( $Te^{2-}$ )	I iodide ( $I^{-}$ )

\*The word “carbide” is also used for the anion  $C_2^{2-}$ .

# Transition metal ionic compounds

Indicate charge on metal with Roman numerals (I, II, III, ..)

3B 4B 5B 6B 7B 8B 1B 2B

$\text{FeCl}_2$     2  $\text{Cl}^-$  -2, so Fe is +2    Iron (II) chloride

$\text{FeCl}_3$     3  $\text{Cl}^-$  -3, so Fe is +3    Iron (III) chloride

$\text{Cr}_2\text{S}_3$     3  $\text{S}^{2-}$  -6, so Cr is +3 (6/2)    Chromium (III) sulfide

If transition metals can form more than one type of cations we use (-ic ) for higher charge and (-ous ) for lower charge .

$\text{FeCl}_2$  iron(II) chloride becomes **ferrous chloride**

$\text{FeCl}_3$  iron(III) chloride becomes **ferric chloride**

$\text{CuCl}$  copper(I) chloride becomes **cuprous chloride**

$\text{CuCl}_2$  copper(II) chloride becomes **cupric chloride**

TABLE 2.3

## Names and Formulas of Some Common Inorganic Cations and Anions

Cation	Anion
aluminum ( $\text{Al}^{3+}$ )	bromide ( $\text{Br}^-$ )
ammonium ( $\text{NH}_4^+$ )	carbonate ( $\text{CO}_3^{2-}$ )
barium ( $\text{Ba}^{2+}$ )	chlorate ( $\text{ClO}_3^-$ )
cadmium ( $\text{Cd}^{2+}$ )	chloride ( $\text{Cl}^-$ )
calcium ( $\text{Ca}^{2+}$ )	chromate ( $\text{CrO}_4^{2-}$ )
cesium ( $\text{Cs}^+$ )	cyanide ( $\text{CN}^-$ )
chromium(III) or chromic ( $\text{Cr}^{3+}$ )	dichromate ( $\text{Cr}_2\text{O}_7^{2-}$ )
cobalt(II) or cobaltous ( $\text{Co}^{2+}$ )	dihydrogen phosphate ( $\text{H}_2\text{PO}_4^-$ )
copper(I) or cuprous ( $\text{Cu}^+$ )	fluoride ( $\text{F}^-$ )
copper(II) or cupric ( $\text{Cu}^{2+}$ )	hydride ( $\text{H}^-$ )
hydrogen ( $\text{H}^+$ )	hydrogen carbonate or bicarbonate ( $\text{HCO}_3^-$ )
iron(II) or ferrous ( $\text{Fe}^{2+}$ )	hydrogen phosphate ( $\text{HPO}_4^{2-}$ )
iron(III) or ferric ( $\text{Fe}^{3+}$ )	hydrogen sulfate or bisulfate ( $\text{HSO}_4^-$ )
lead(II) or plumbous ( $\text{Pb}^{2+}$ )	hydroxide ( $\text{OH}^-$ )
lithium ( $\text{Li}^+$ )	iodide ( $\text{I}^-$ )
magnesium ( $\text{Mg}^{2+}$ )	nitrate ( $\text{NO}_3^-$ )
manganese(II) or manganous ( $\text{Mn}^{2+}$ )	nitride ( $\text{N}^{3-}$ )
mercury(I) or mercurous ( $\text{Hg}_2^{2+}$ )*	nitrite ( $\text{NO}_2^-$ )
mercury(II) or mercuric ( $\text{Hg}^{2+}$ )	oxide ( $\text{O}^{2-}$ )
potassium ( $\text{K}^+$ )	permanganate ( $\text{MnO}_4^-$ )
rubidium ( $\text{Rb}^+$ )	peroxide ( $\text{O}_2^{2-}$ )
silver ( $\text{Ag}^+$ )	phosphate ( $\text{PO}_4^{3-}$ )
sodium ( $\text{Na}^+$ )	sulfate ( $\text{SO}_4^{2-}$ )
strontium ( $\text{Sr}^{2+}$ )	sulfide ( $\text{S}^{2-}$ )
tin(II) or stannous ( $\text{Sn}^{2+}$ )	sulfite ( $\text{SO}_3^{2-}$ )
zinc ( $\text{Zn}^{2+}$ )	thiocyanate ( $\text{SCN}^-$ )

\*Mercury(I) exists as a pair as shown.

## EXAMPLE 2.5

Name the following compounds: (a)  $\text{Cu}(\text{NO}_3)_2$ , (b)  $\text{KH}_2\text{PO}_4$ , and (c)  $\text{NH}_4\text{ClO}_3$ .

### Solution

- (a) The nitrate ion ( $\text{NO}_3^-$ ) bears one negative charge, so the copper ion must have two positive charges. Because copper forms both  $\text{Cu}^+$  and  $\text{Cu}^{2+}$  ions, we need to use the Stock system and call the compound copper(II) nitrate.
- (b) The cation is  $\text{K}^+$  and the anion is  $\text{H}_2\text{PO}_4^-$  (dihydrogen phosphate). Because potassium only forms one type of ion ( $\text{K}^+$ ), there is no need to use potassium(I) in the name. The compound is potassium dihydrogen phosphate.
- (c) The cation is  $\text{NH}_4^+$  (ammonium ion) and the anion is  $\text{ClO}_3^-$ . The compound is ammonium chlorate.

## EXAMPLE 2.6

Write chemical formulas for the following compounds: (a) mercury(I) nitrite, (b) cesium sulfide, and (c) calcium phosphate.

**Strategy** We refer to Table 2.3 for the formulas of cations and anions. Recall that the Roman numerals in the Stock system provide useful information about the charges of the cation.

### Solution

- (a) The Roman numeral shows that the mercury ion bears a +1 charge. According to Table 2.3, however, the mercury(I) ion is diatomic (that is,  $\text{Hg}_2^{2+}$ ) and the nitrite ion is  $\text{NO}_2^-$ . Therefore, the formula is  $\text{Hg}_2(\text{NO}_2)_2$ .
- (b) Each sulfide ion bears two negative charges, and each cesium ion bears one positive charge (cesium is in Group 1A, as is sodium). Therefore, the formula is  $\text{Cs}_2\text{S}$ .
- (c) Each calcium ion ( $\text{Ca}^{2+}$ ) bears two positive charges, and each phosphate ion ( $\text{PO}_4^{3-}$ ) bears three negative charges. To make the sum of the charges equal zero, we must adjust the numbers of cations and anions:

$$3(+2) + 2(-3) = 0$$

Thus, the formula is  $\text{Ca}_3(\text{PO}_4)_2$ .

# Molecular Compounds

- They are usually composed of nonmetallic elements.
- Many molecular compounds are binary compounds.
- Naming binary molecular compounds is similar to naming binary ionic compounds.
- We place the name of the first element in the formula first, and the second element is named by adding *-ide* to the root of the element name.

HCl    hydrogen chloride

HBr    hydrogen bromide

SiC    silicon carbide



If a pair of elements form more than one compound, use prefixes to indicate number of each kind of atom

### Notes in naming compounds with prefixes:

The prefix “mono-” may be omitted for the first element.

*For example*,  $\text{PCl}_3$  is named phosphorus trichloride, not ~~monophosphorus trichloride~~.

For oxides, the ending “a” in the prefix is **sometimes** omitted.

*For example*,  $\text{N}_2\text{O}_4$  may be called dinitrogen **tet**roxide rather than dinitrogen ~~tetra~~oxide.

**TABLE 2.4**

### Greek Prefixes Used in Naming Molecular Compounds

Prefix	Meaning
mono-	1
di-	2
tri-	3
tetra-	4
penta-	5
hexa-	6
hepta-	7
octa-	8
nona-	9
deca-	10

## Name the following compounds:

HI          hydrogen iodide

NF<sub>3</sub>        nitrogen trifluoride

SO<sub>2</sub>        sulfur dioxide

N<sub>2</sub>Cl<sub>4</sub>       dinitrogen tetrachloride

NO<sub>2</sub>        nitrogen dioxide

N<sub>2</sub>O         dinitrogen monoxide

## EXAMPLE 2.7

Name the following molecular compounds: (a)  $\text{SiCl}_4$  and (b)  $\text{P}_4\text{O}_{10}$ .

**Strategy** We refer to Table 2.4 for prefixes. In (a) there is only one Si atom so we do not use the prefix “mono.”

**Solution** (a) Because there are four chlorine atoms present, the compound is silicon tetrachloride.

(b) There are four phosphorus atoms and ten oxygen atoms present, so the compound is tetraphosphorus decoxide. Note that the “a” is omitted in “deca.”

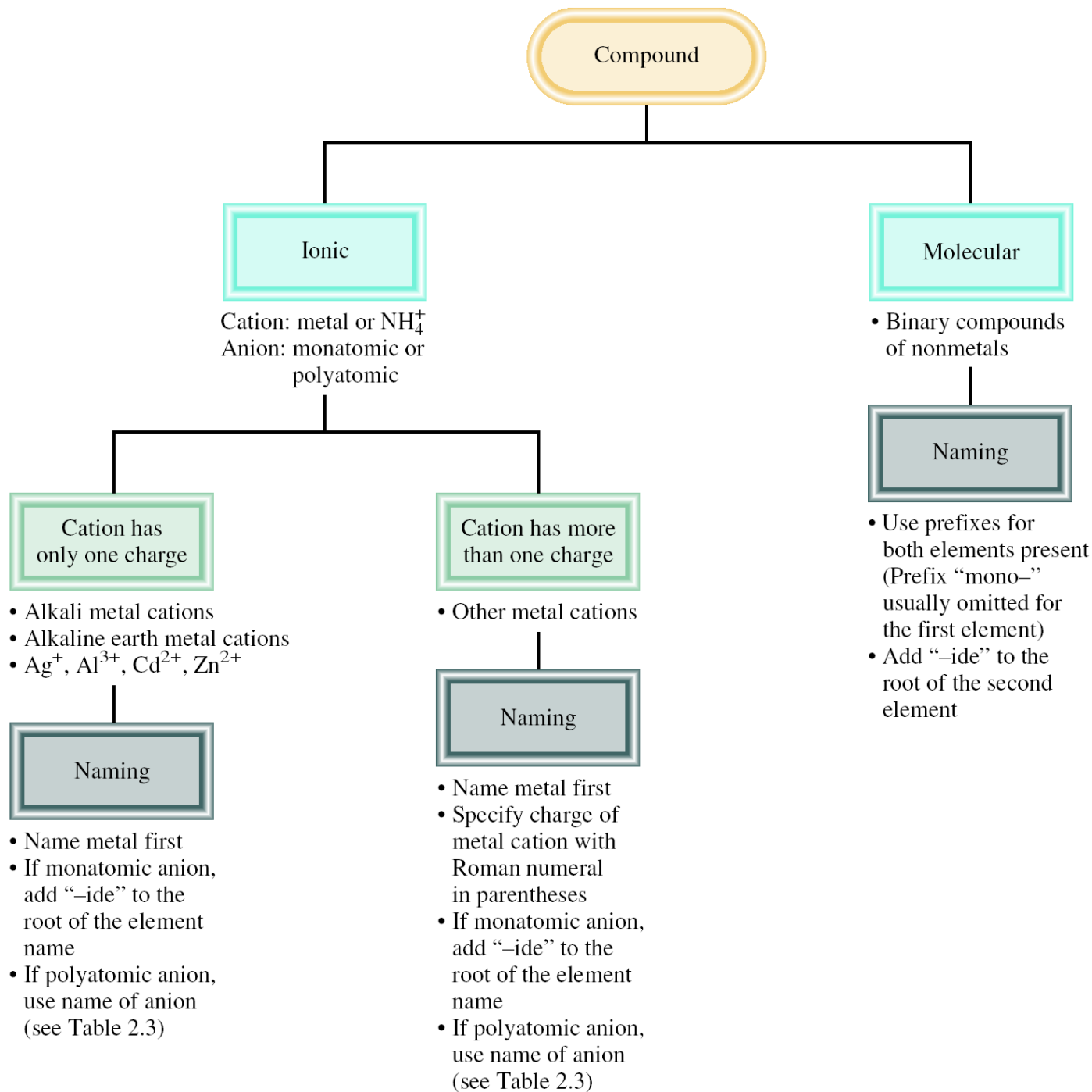
## EXAMPLE 2.8

Write chemical formulas for the following molecular compounds: (a) carbon disulfide and (b) disilicon hexabromide.

**Strategy** Here we need to convert prefixes to numbers of atoms (see Table 2.4). Because there is no prefix for carbon in (a), it means that there is only one carbon atom present.

**Solution** (a) Because there are two sulfur atoms and one carbon atom present, the formula is  $\text{CS}_2$ .

(b) There are two silicon atoms and six bromine atoms present, so the formula is  $\text{Si}_2\text{Br}_6$ .



# Acids

An **acid** can be defined as a substance that yields hydrogen ions ( $\text{H}^+$ ) when dissolved in water.

**For example:** HCl gas and HCl in water

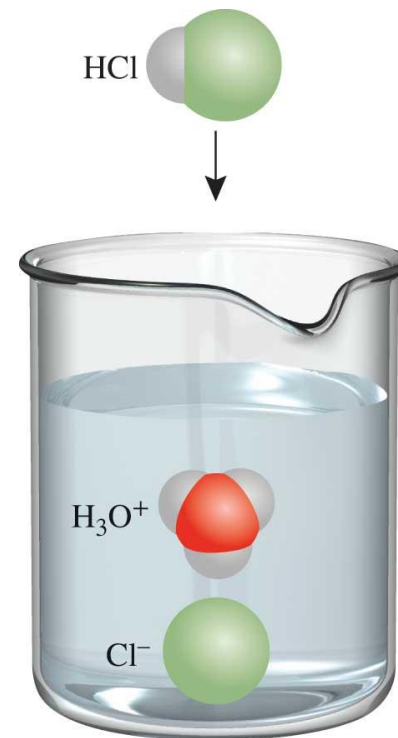
Pure substance: hydrogen chloride

Dissolved in water ( $\text{H}_3\text{O}^+$  and  $\text{Cl}^-$ ),  
hydrochloric acid

Anions whose names end in “-ide” form acids with a “hydro-” prefix and an “-ic” ending.

HCl      hydrogen chloride

HCl      hydrochloric acid



# Some Examples of Acids

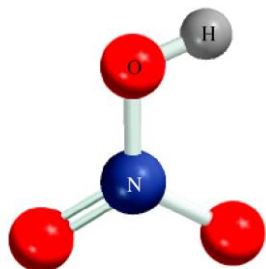
**TABLE 2.5** Some Simple Acids

<b>Anion</b>	<b>Corresponding Acid</b>
$F^-$ (fluoride)	HF (hydrofluoric acid)
$Cl^-$ (chloride)	HCl (hydrochloric acid)
$Br^-$ (bromide)	HBr (hydrobromic acid)
$I^-$ (iodide)	HI (hydroiodic acid)
$CN^-$ (cyanide)	HCN (hydrocyanic acid)
$S^{2-}$ (sulfide)	$H_2S$ (hydrosulfuric acid)

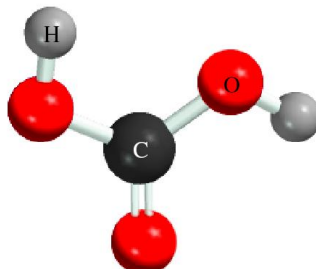
# Naming Oxoacids and Oxoanions

An ***oxoacid*** is an acid that contains hydrogen, oxygen, and another element.

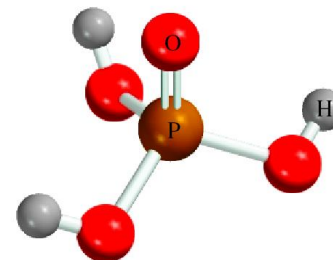
nitric acid



carbonic acid



phosphoric acid



The formulas of ***oxoacids*** are usually written with the H first, followed by the central element and then O.

$\text{H}_2\text{CO}_3$  (carbonic acid),  $\text{HClO}_3$  (chloric acid),

$\text{HNO}_3$  (nitric acid),  $\text{H}_3\text{PO}_4$  (phosphoric acid),

$\text{H}_2\text{SO}_4$  (sulfuric acid)

Two or more **oxoacids** have the same central atom but a different number of O atoms; the following rules to name these compounds.

1. **Addition of one O atom to the “-ic” acid:** The acid is called “per . . -ic” acid. ( --ate)



2. **Removal of one O atom from the “-ic” acid:** The acid is called “-ous” acid. ( --ite)



3. **Removal of two O atoms from the “-ic” acid:** The acid is called “hypo . . . -ous” acid.





The rules for naming *oxoanions, anions of oxoacids*, are as follows:

1. When all the **H ions are removed** from the **“-ic” acid**, the anion’s name ends with **“-ate.”**
2. When all the **H ions are removed** from the **“-ous” acid**, the anion’s name ends with **“-ite.”**
3. The names of anions in which one or more but not all the hydrogen ions have been removed must indicate the number of H ions present.

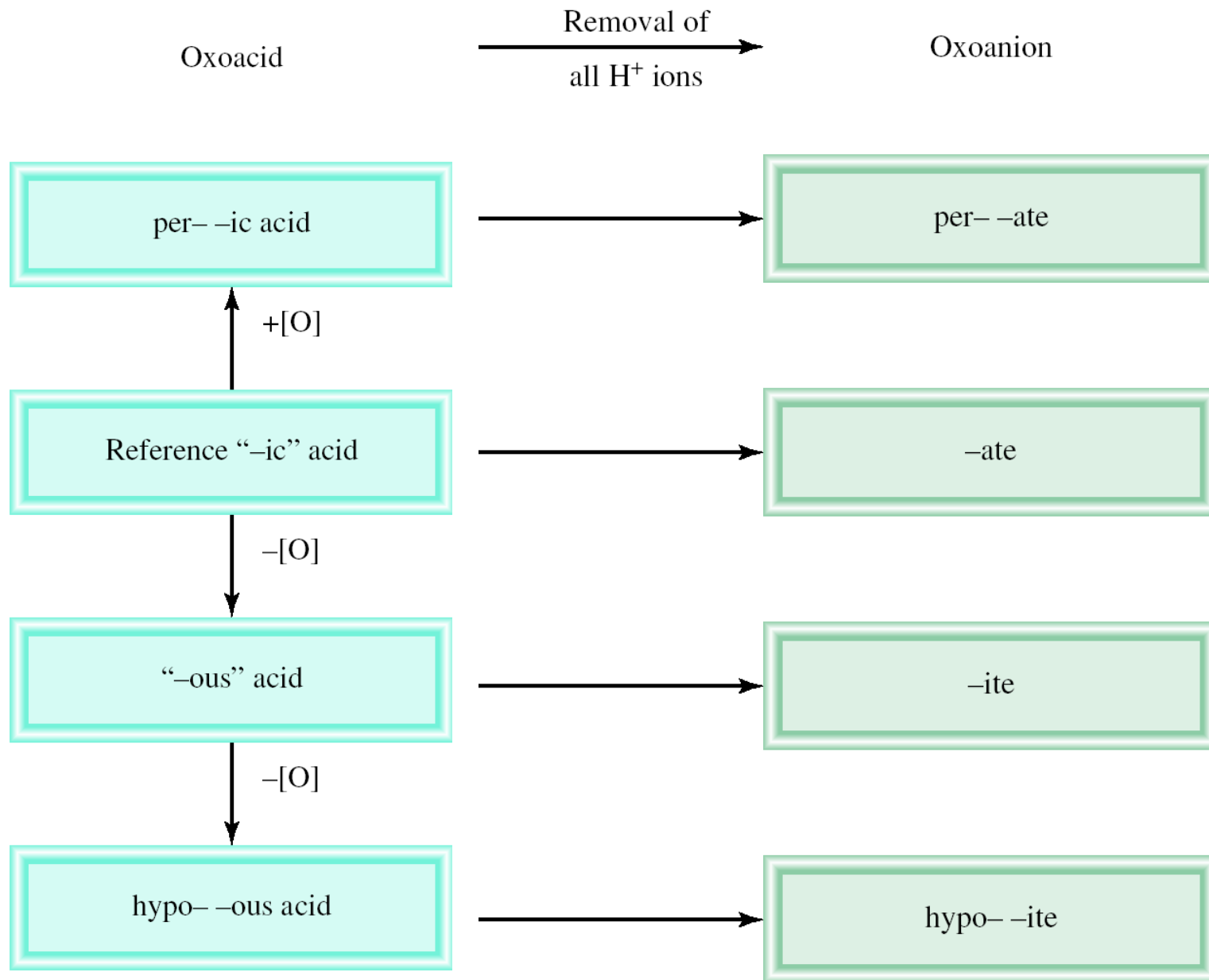
**For example:**

- $\text{H}_3\text{PO}_4$       phosphoric acid
- $\text{H}_2\text{PO}_4^-$       dihydrogen phosphate
- $\text{HPO}_4^{2-}$       hydrogen phosphate
- $\text{PO}_4^{3-}$       phosphate

**TABLE 2.6** Names of Oxoacids and Oxoanions That Contain Chlorine

<b>Acid</b>	<b>Anion</b>
HClO <sub>4</sub> (perchloric acid)	ClO <sub>4</sub> <sup>-</sup> (perchlorate)
HClO <sub>3</sub> (chloric acid)	ClO <sub>3</sub> <sup>-</sup> (chlorate)
HClO <sub>2</sub> (chlorous acid)	ClO <sub>2</sub> <sup>-</sup> (chlorite)
HClO (hypochlorous acid)	ClO <sup>-</sup> (hypochlorite)

parent acid for all halogenic acids is:  
HXO<sub>3</sub> Halogenic acid



## EXAMPLE 2.9

Name the following oxoacid and oxoanion: (a)  $\text{H}_3\text{PO}_3$  and (b)  $\text{IO}_4^-$ .

**Solution** (a) We start with our reference acid, phosphoric acid ( $\text{H}_3\text{PO}_4$ ). Because  $\text{H}_3\text{PO}_3$  has one fewer O atom, it is called phosphorous acid.

(b) The parent acid is  $\text{HIO}_4$ . Because the acid has one more O atom than our reference iodic acid ( $\text{HIO}_3$ ), it is called periodic acid. Therefore, the anion derived from  $\text{HIO}_4$  is called periodate.

# Bases

A **base** can be defined as a substance that yields hydroxide ions (**OH<sup>-</sup>**) when dissolved in water.

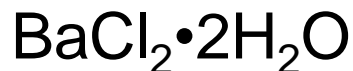
NaOH                      sodium hydroxide

KOH                        potassium hydroxide

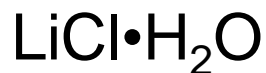
Ba(OH)<sub>2</sub>                barium hydroxide

# Hydrated Compounds

**Hydrates** are compounds that have a specific number of water molecules attached to them.



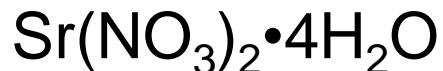
barium chloride dihydrate



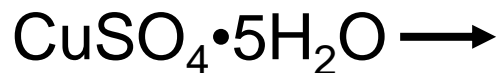
lithium chloride monohydrate



magnesium sulfate heptahydrate



strontium nitrate tetrahydrate



# Common and Systematic Names of Compounds

**Table 2.7** Common and Systematic Names of Some Compounds

Formula	Common Name	Systematic Name
H <sub>2</sub> O	Water	Dihydrogen monoxide
NH <sub>3</sub>	Ammonia	Trihydrogen nitride
CO <sub>2</sub>	Dry ice	Solid carbon dioxide
NaCl	Table salt	Sodium chloride
N <sub>2</sub> O	Laughing gas	Dinitrogen monoxide
CaCO <sub>3</sub>	Marble, chalk, limestone	Calcium carbonate
CaO	Quicklime	Calcium oxide
Ca(OH) <sub>2</sub>	Slaked lime	Calcium hydroxide
NaHCO <sub>3</sub>	Baking soda	Sodium hydrogen carbonate
Na <sub>2</sub> CO <sub>3</sub> ·10H <sub>2</sub> O	Washing soda	Sodium carbonate decahydrate
MgSO <sub>4</sub> ·7H <sub>2</sub> O	Epsom salt	Magnesium sulfate heptahydrate
Mg(OH) <sub>2</sub>	Milk of magnesia	Magnesium hydroxide
CaSO <sub>4</sub> ·2H <sub>2</sub> O	Gypsum	Calcium sulfate dihydrate