General Chemistry

CHEM 101
(3+1+0)

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Chapter 2

Chemistry: *Atoms*, *Molecules* and *Ions*

The Structure of the Atom

Dalton's Atomic Theory (1808)

- ***Compounds*** are composed of atoms of more than one element.
- Elements are composed of extremely small particles called ***atoms***.
- A ***chemical reaction*** involves only the separation, combination, or rearrangement of atoms; it does not result in their creation or destruction.

The Structure of the Atom

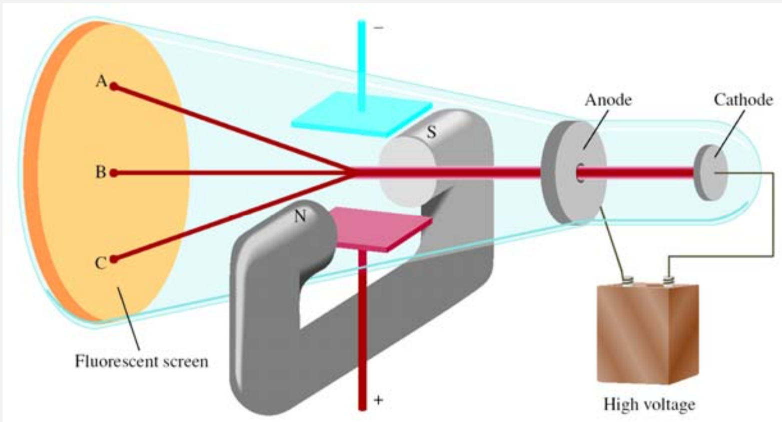
Dalton's Atomic Theory (1808)

- ***Atom*** is the basic unit of an element that can enter into chemical combination.
- Dalton imagined an ***atom*** that was both extremely small and indivisible.
- The 1850s and extended into the twentieth century: ***atoms*** *actually possess internal structure; they are made up of even smaller particles, which are called subatomic particles.*
- This research led to the discovery of three such particles - **electrons**, **protons**, and **neutrons**.

The Structure of the Atom

The Electron

- ***Radiation*** - the *emission and transmission of energy through space in the form of waves*.
- One device used to investigate this phenomenon was a ***cathode ray tube*** **(***It is a glass tube from which most of the air has been evacuated***)**.

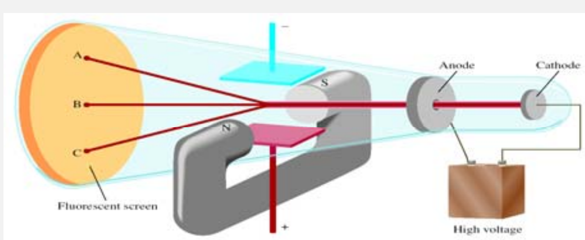


The Structure of the Atom

The Electron

When the two metal plates are connected to a high-voltage source;

- The negatively charged plate, called the *cathode*, emits an invisible ray.
- The cathode ray is drawn to the positively charged plate, called the *anode*, where it passes through a hole and continues traveling to the other end of the tube.
- When the ray strikes the specially coated surface, it produces a strong fluorescence, or bright light.

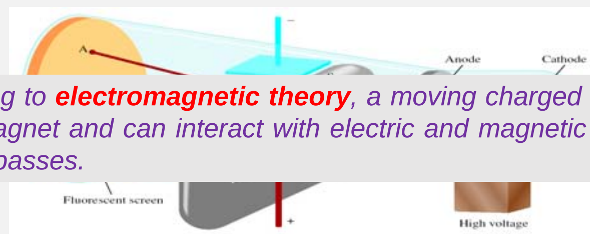


The Structure of the Atom

The Electron

In some experiments, two electrically charged plates and a magnet were added to the *outside* of the cathode ray tube.

- When the **magnetic field is on and the electric field is off**, the cathode ray strikes point A.
- When **only the electric field is on**, the ray strikes point C.
- When **both the magnetic and the electric fields are off or when they are both on** but balanced so that they cancel each other's influence, the ray strikes point B.



*According to **electromagnetic theory**, a moving charged body behaves like a magnet and can interact with electric and magnetic fields through which it passes.*

The Structure of the Atom

The Electron

- Because the cathode ray is attracted by the plate bearing positive charges and repelled by the plate bearing negative charges, it must consist of ***negatively charged particles***.
- We know these *negatively charged particles* as ***electrons*.**

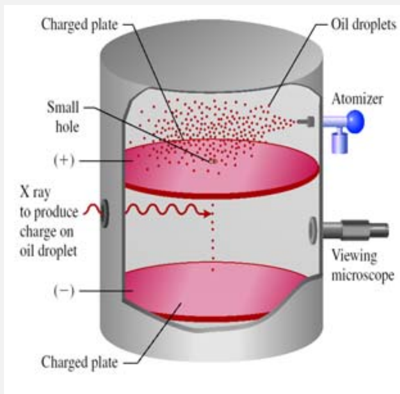
J.J. Thomson, measured mass/charge of e^-

(1906 Nobel Prize in Physics)

Thomson's charge/mass of e^- = -1.76×10^8 C/g

The Structure of the Atom

Millikan's Experiment



Measured mass of e⁻

(1923 Nobel Prize in Physics)

- Millikan examined the motion of single tiny drops of oil that picked up static charge from ions in the air.
- He suspended the charged drops in air by applying an electric field and followed their motions through a microscope.

e⁻ charge = -1.60×10^{-19} C
Thomson's charge/mass of e⁻ = -1.76×10^{8} C/g
e⁻ mass = 9.10×10^{-28} g

$$\text{mass of an electron} = \frac{\text{charge}}{\text{charge/mass}} = \frac{-1.6022 \times 10^{-19}\,\text{C}}{-1.76 \times 10^{8}\,\text{C/g}} = 9.10 \times 10^{-28}\,\text{g}$$

The Structure of the Atom

Radioactivity

- It was suggested by Marie Curie.
- ***Radioactivity*** - spontaneous emission of particles and/or radiation.
- ***Radioactive*** - any element that spontaneously emits radiation.
- ***Röntgen*** noticed that cathode rays caused glass and metals to emit very unusual rays.
  - Highly energetic radiation penetrated matter, darkened covered photographic plates, and caused a variety of substances to fluoresce.
  - These rays could not be deflected by a magnet, they could not contain charged particles as cathode rays do.
  - Röntgen called them ***X rays*** because their nature was not known.

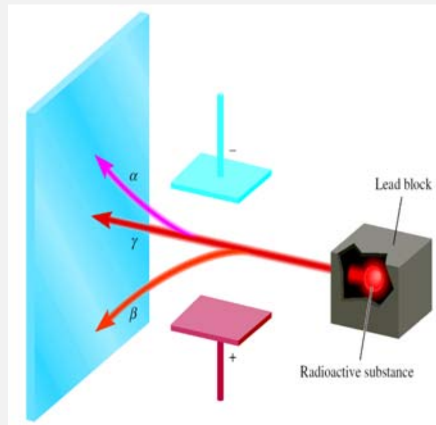
The Structure of the Atom

Radioactivity

Three types of rays **are produced by the** ***decay,*** **or breakdown, of radioactive substances such as uranium.**

1. Two of the three are deflected by oppositely charged metal plates.
   - ***Alpha (α) rays or α particles;*** *positively charged particles,* and are deflected by the positively charged plate.
   - ***Beta (β) rays*** or ***β particles;*** are *electrons* and are deflected by the negatively charged plate.
2. ***Gamma (γ) rays;*** high-energy rays.

   Like X rays, γ rays have no charge and are not affected by an external field.



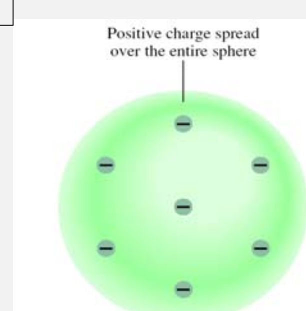
The Structure of the Atom

The Proton and the Nucleus

- By the early 1900s, two features of atoms had become clear: *they contain electrons, and they are electrically neutral*.
- To maintain electric neutrality, *an atom must contain an equal number of positive and negative charges*.

Thomson's Model

- a uniform, positive sphere of matter in which electrons are embedded like raisins in a cake.
- This so-called "***plum-pudding***" model was the accepted theory for a number of years.

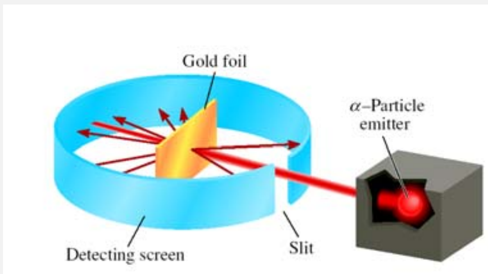


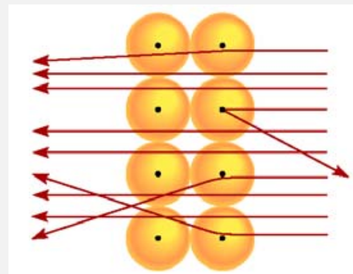
The Structure of the Atom

The Proton and the Nucleus

Rutherford's Experiment

(1908 Nobel Prize in Chemistry)





α particle velocity ~ 1.4×10^7 m/s
(~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 x mass of e^- (1.67×10^{-24} g)

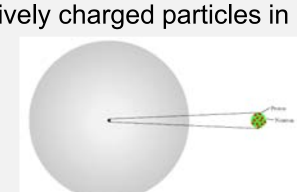
The Structure of the Atom

The Proton and the Nucleus

Rutherford's Model of the Atom

- Most of the atom must be empty space.

  This explains why the majority of a particles passed through the gold foil with little or no deflection.
- The atom's positive charges, are all concentrated in the *nucleus*, which is *a dense central core within the atom.*
- Whenever an α particle came close to a nucleus in the scattering experiment, a large repulsive force and therefore a large deflection.
- The positively charged particles in the nucleus are called ***protons*** .



atomic radius ~ 100 pm = 1×10^{-10} m

nuclear radius ~ 5×10^{-3} pm = 5×10^{-15} m

The Structure of the Atom

The Neutron

Chadwick's Experiment (1932)

(1935 Noble Prize in Physics)

- **When a thin sheet of beryllium was bombarded with a particles, a very high-energy radiation similar to γ rays was emitted by the metal.**
- **Later experiments showed that the rays actually consisted of a third type of subatomic particles, which Chadwick named *neutrons*, *electrically neutral particles having a mass slightly greater than that of protons*.**

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 ~ p mass = 1.67×10^{-24} g

The Structure of the Atom

The Neutron

TABLE 2.1 Mass and Charge of Subatomic Particles

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

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

mass p ≈ mass n ≈ 1840 x mass e^-

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

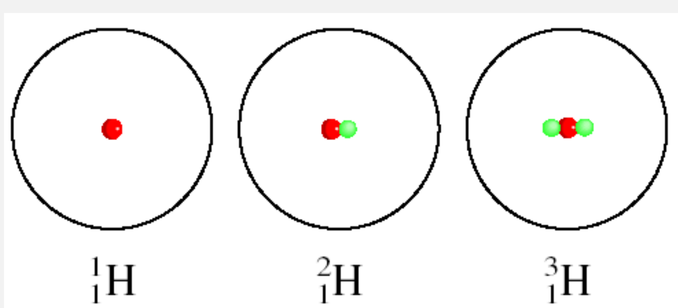
Mass Number → $^{A}_{Z}X$ ← Element Symbol
Atomic Number →

$^{1}_{1}H$ hydrogen $^{2}_{1}H$ (D) deuterium $^{3}_{1}H$ (T) tritium

$^{235}_{92}U$ $^{238}_{92}U$

Atomic Number, Mass Number and Isotopes

The Isotopes of Hydrogen



Atomic Number, Mass Number and Isotopes

How many protons, neutrons, and electrons are in $^{14}_{6}C$?

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

How many protons, neutrons, and electrons are in $^{11}_{6}C$?

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

Atomic Number, Mass Number and Isotopes

EXAMPLE 2.1

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

Strategy Recall that the superscript denotes the mass number (*A*) and the subscript denotes the atomic number (*Z*). Mass number is always greater than atomic number. (The only exception is $^{1}_{1}H$, where the mass number is equal to the atomic number.) In a case where no subscript is shown, as in parts (c) and (d), the atomic number can be deduced from the element symbol or name. To determine the number of electrons, remember that because atoms are electrically neutral, the number of electrons is equal to the number of protons.

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.

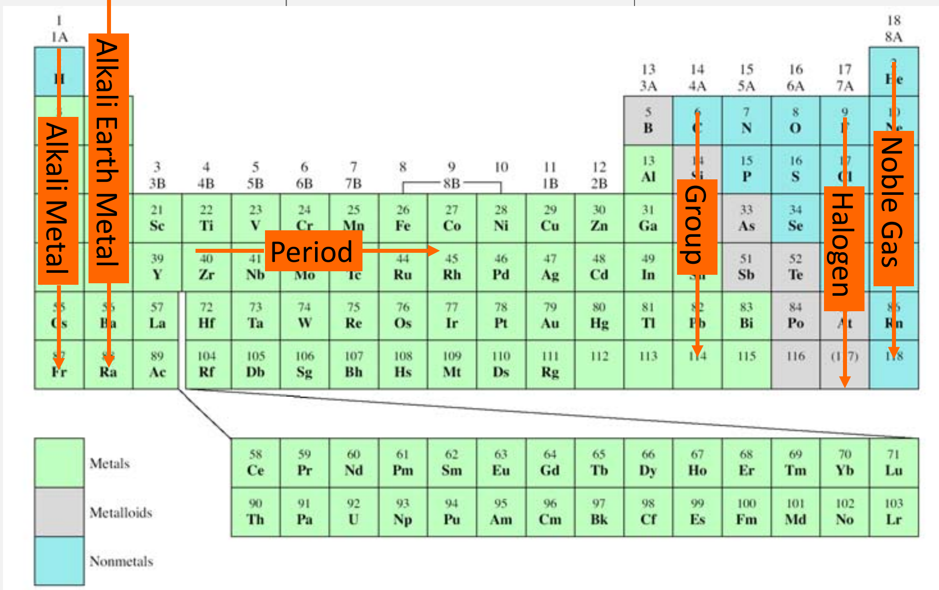
(b) The atomic number is the same as that in (a), or 11. The mass number is 22, so the number of neutrons is 22 − 11 = 11. The number of electrons is 11. Note that the species in (a) and (b) are chemically similar isotopes of sodium.

(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}C. The atomic number of carbon is 6, so there are 14 − 6 = 8 neutrons. The number of electrons is 6.

Practice Exercise How many protons, neutrons, and electrons are in the following isotope of copper: ^{63}Cu?

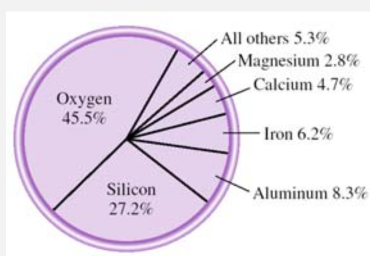
The Periodic Table



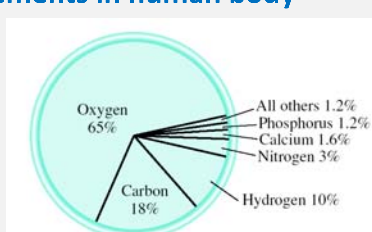
The Periodic Table

Chemistry In Action

Natural abundance of elements in Earth's crust

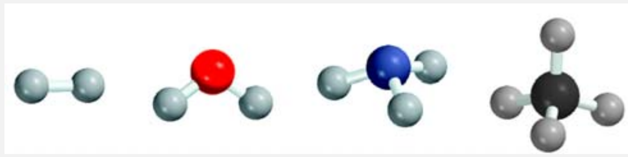


Natural abundance of elements in human body



Molécules and Ions

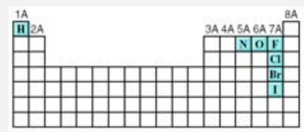
- A ***molecule*** is an aggregate of two or more atoms in a definite arrangement held together by chemical forces.



H_2 H_2O NH_3 CH_4

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

H_2, N_2, O_2, Br_2, HCl, CO



diatomic elements

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

O_3, H_2O, NH_3, CH_4

Molécules and 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.

Na — 11 protons, 11 electrons

Na^+ — 11 protons, 10 electrons

anion – ion with a negative charge
If a neutral atom **gains** one or more electrons
it becomes an anion.

Cl — 17 protons, 17 electrons

Cl^- — 17 protons, 18 electrons

Molécules and Ions

- A ***monatomic ion*** contains only one atom

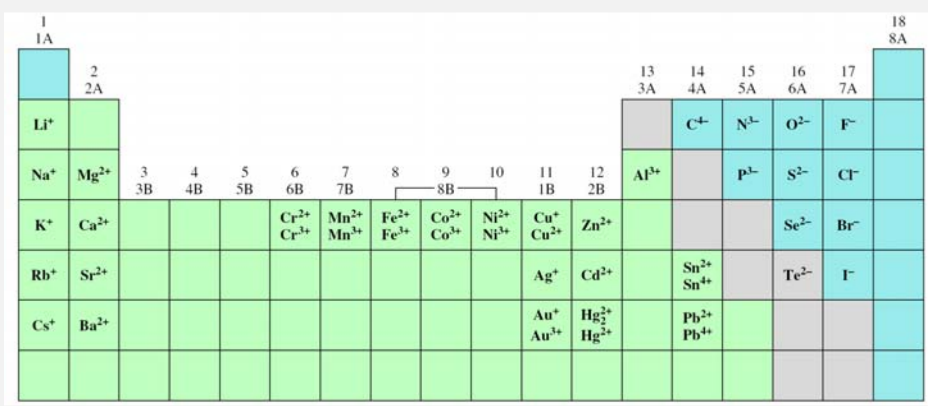
Na^{+}, Cl^{-}, Ca^{2+}, O^{2-}, Al^{3+}, N^{3-}

- A ***polyatomic ion*** contains more than one atom

OH^{-}, CN^{-}, NH_4^{+}, NO_3^{-}

Molécules and Ions

Common Ions Shown on the Periodic Table



Molécules and Ions

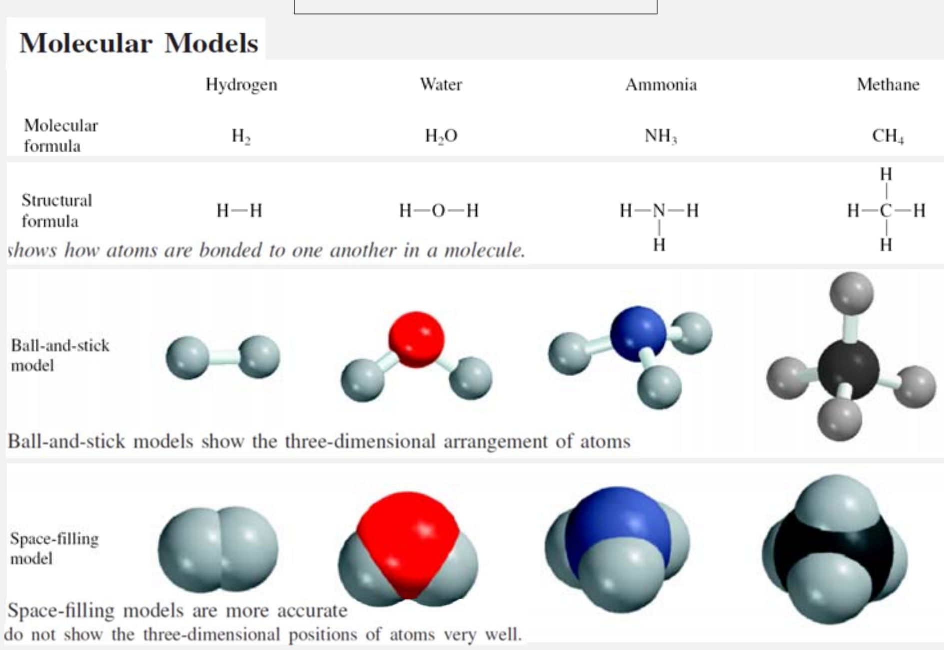
How many protons and electrons are in $^{27}_{13}Al^{3+}$?

13 protons, 10 (13 – 3) electrons

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

34 protons, 36 (34 + 2) electrons

Chemical Formulas



Chemical 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***

molecular	**empirical**
H_2O	H_2O
$C_6H_{12}O_6$	CH_2O
O_3	O
N_2H_4	NH_2

- An ***allotrope*** is ***one of two or more distinct forms of an element***.

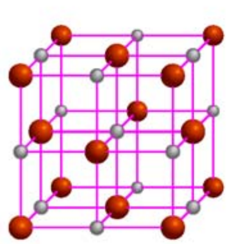
Oxygen (O_2) and ozone (O_3) are allotropes of oxygen.

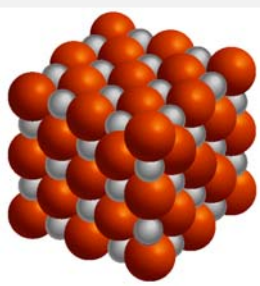
diamond and graphite are allotropes of carbon.

Chemical Formulas

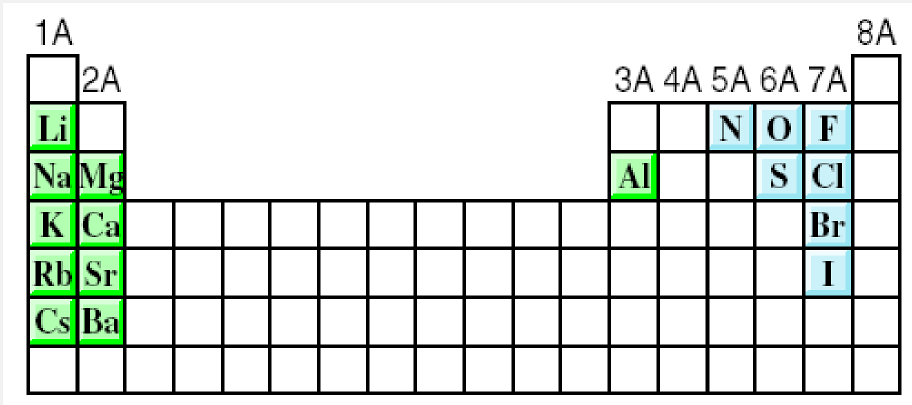
- ***Ionic compounds*** consist of a combination of cations and an anions
  - The formula is usually the same as the empirical formula
  - The sum of the charges on the cation(s) and anion(s) in each formula unit must equal zero

The ionic compound NaCl





Chemical Formulas



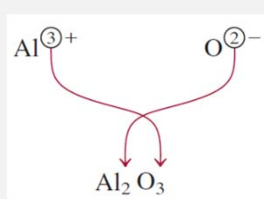
The most reactive **metals** (green) and the most reactive **nonmetals** (blue) combine to form ionic compounds.

Chemical Formulas

- 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 Al^{3+} and the oxygen anion is O^{2-}.



The sum of the charges is 2(+3) + 3(-2) = 0.
Thus, the formula for aluminum oxide is Al_2O_3.

Chemical Formulas

Formula of Ionic Compounds

2 x +3 = +6   3 x -2 = -6

Al_2O_3

Al^{3+} O^{2-}

1 x +2 = +2   2 x -1 = -2

$CaBr_2$

Ca^{2+} Br^-

1 x +2 = +2   1 x -2 = -2

Na_2CO_3

Na^+ CO_3^{2-}

Chemical Formulas

EXAMPLE 2.4

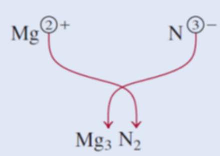
Write the formula of magnesium nitride, containing the Mg^{2+} and N^{3-} ions.

Strategy Our guide for writing formulas for ionic compounds is electrical neutrality; that is, the total charge on the cation(s) must be equal to the total charge on the anion(s). Because the charges on the Mg^{2+} and N^{3-} ions are not equal, we know the formula cannot be MgN. Instead, we write the formula as Mg_xN_y, where x and y are subscripts to be determined.

Solution To satisfy electrical neutrality, the following relationship must hold:

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

Solving, we obtain $x/y = 3/2$. Setting $x = 3$ and $y = 2$, we write



Check The subscripts are reduced to the smallest whole number ratio of the atoms because the chemical formula of an ionic compound is usually its empirical formula.

Practice Exercise Write the formulas of the following ionic compounds: (a) chromium sulfate (containing the Cr^{3+} and SO_4^{2-} ions) and (b) titanium oxide (containing the Ti^{4+} and O^{2-} ions).

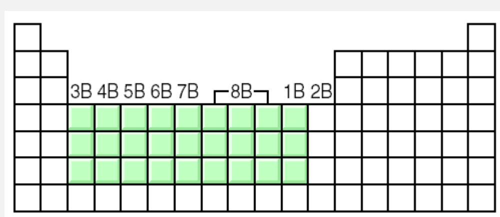
Naming Compounds

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

$BaCl_2$	barium chloride
K_2O	potassium oxide
$Mg(OH)_2$	magnesium hydroxide
KNO_3	potassium nitrate

Naming Compounds

- Transition metal ionic compounds
  - indicate charge on metal with Roman numerals



$FeCl_2$	2 Cl^- -2 so Fe is +2	iron(II) chloride
$FeCl_3$	3 Cl^- -3 so Fe is +3	iron(III) chloride
Cr_2S_3	3 S^{-2} -6 so Cr is +3 (6/2)	chromium(III) sulfide

Naming Compounds

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-}.

Naming Compounds

TABLE 2.3 Names and Formulas of Some Common Inorganic Cations and Anions

Cation	Anion
aluminum (Al^{3+})	bromide (Br^-)
ammonium (NH_4^+)	carbonate (CO_3^{2-})
barium (Ba^{2+})	chlorate (ClO_3^-)
cadmium (Cd^{2+})	chloride (Cl^-)
calcium (Ca^{2+})	chromate (CrO_4^{2-})
cesium (Cs^+)	cyanide (CN^-)
chromium(III) or chromic (Cr^{3+})	dichromate ($Cr_2O_7^{2-}$)
cobalt(II) or cobaltous (Co^{2+})	dihydrogen phosphate ($H_2PO_4^-$)
copper(I) or cuprous (Cu^+)	fluoride (F^-)
copper(II) or cupric (Cu^{2+})	hydride (H^-)
hydrogen (H^+)	hydrogen carbonate or bicarbonate (HCO_3^-)
iron(II) or ferrous (Fe^{2+})	hydrogen phosphate (HPO_4^{2-})
iron(III) or ferric (Fe^{3+})	hydrogen sulfate or bisulfate (HSO_4^-)
lead(II) or plumbous (Pb^{2+})	hydroxide (OH^-)
lithium (Li^+)	iodide (I^-)
magnesium (Mg^{2+})	nitrate (NO_3^-)
manganese(II) or manganous (Mn^{2+})	nitride (N^{3-})
mercury(I) or mercurous (Hg_2^{2+})*	nitrite (NO_2^-)
mercury(II) or mercuric (Hg^{2+})	oxide (O^{2-})
potassium (K^+)	permanganate (MnO_4^-)
rubidium (Rb^+)	peroxide (O_2^{2-})
silver (Ag^+)	phosphate (PO_4^{3-})
sodium (Na^+)	sulfate (SO_4^{2-})
strontium (Sr^{2+})	sulfide (S^{2-})
tin(II) or stannous (Sn^{2+})	sulfite (SO_3^{2-})
zinc (Zn^{2+})	thiocyanate (SCN^-)

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

Naming Compounds

EXAMPLE 2.5

Name the following compounds: (a) $Cu(NO_3)_2$, (b) KH_2PO_4, and (c) NH_4ClO_3.

Strategy Note that the compounds in (a) and (b) contain both metal and nonmetal atoms, so we expect them to be ionic compounds. There are no metal atoms in (c) but there is an ammonium group, which bears a positive charge. So NH_4ClO_3 is also an ionic compound. Our reference for the names of cations and anions is Table 2.3. Keep in mind that if a metal atom can form cations of different charges (see Figure 2.11), we need to use the Stock system.

Solution

(a) The nitrate ion (NO_3^-) bears one negative charge, so the copper ion must have two positive charges. Because copper forms both Cu^+ and Cu^{2+} ions, we need to use the Stock system and call the compound copper(II) nitrate.

(b) The cation is K^+ and the anion is $H_2PO_4^-$ (dihydrogen phosphate). Because potassium only forms one type of ion (K^+), there is no need to use potassium(I) in the name. The compound is potassium dihydrogen phosphate.

(c) The cation is NH_4^+ (ammonium ion) and the anion is ClO_3^-. The compound is ammonium chlorate.

Practice Exercise Name the following compounds: (a) PbO and (b) Li_2SO_3.

Naming Compounds

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, Hg_2^{2+}) and the nitrite ion is NO_2^-. Therefore, the formula is $Hg_2(NO_2)_2$.

(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 Cs_2S.

(c) Each calcium ion (Ca^{2+}) bears two positive charges, and each phosphate ion (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 $Ca_3(PO_4)_2$.

Practice Exercise Write formulas for the following ionic compounds: (a) rubidium sulfate and (b) barium hydride.

Naming Compounds

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 fi rst 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

Naming Compounds

Molecular compounds

- If more than one compound can be formed from the same elements, use prefixes to indicate number of each kind of atom

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

Naming Compounds

Molecular compounds

HI	hydrogen iodide
NF_3	nitrogen trifluoride
SO_2	sulfur dioxide
N_2Cl_4	dinitrogen tetrachloride
NO_2	nitrogen dioxide
N_2O	dinitrogen monoxide

Naming Compounds

Molecular compounds

Notes in naming compounds with prefixes:

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

  For example**,** PCl_3 is named phosphorus trichloride, not monophosphorus trichloride.
- For oxides, the ending "a" in the prefix is sometimes omitted.

  For example**,** N_2O_4 may be called dinitrogen tetroxide rather than dinitrogen tetraoxide.

Naming Compounds

EXAMPLE 2.7

Name the following molecular compounds: (a) $SiCl_4$ and (b) P_4O_{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."

Practice Exercise Name the following molecular compounds: (a) NF_3 and (b) Cl_2O_7.

EXAMPLE 2.8

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

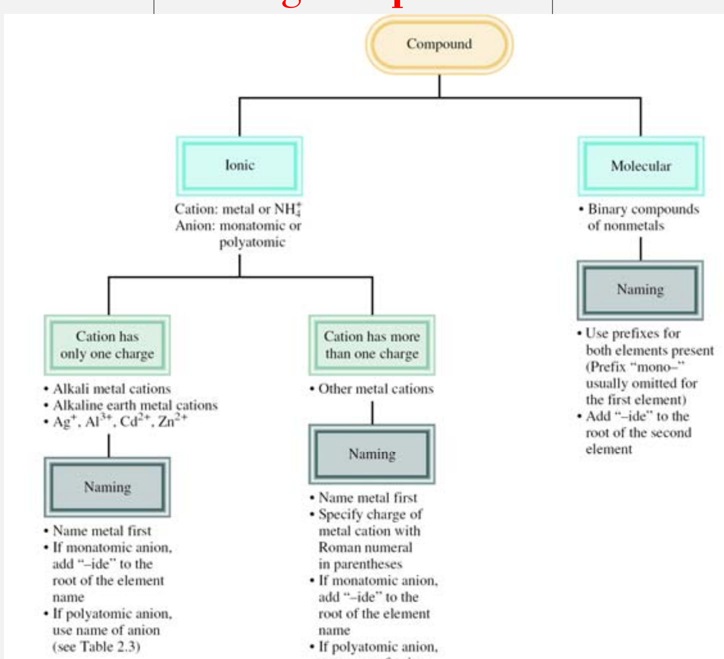
Strategy Here we need to convert prefixes to numbers of atoms (see Table 2.4). Because there is no prefix for carbon in (a), it means that there is only one carbon atom present.

Solution (a) Because there are two sulfur atoms and one carbon atom present, the formula is CS_2.

(b) There are two silicon atoms and six bromine atoms present, so the formula is Si_2Br_6.

Practice Exercise Write chemical formulas for the following molecular compounds: (a) sulfur tetrafluoride and (b) dinitrogen pentoxide.

Naming Compounds



Naming Compounds

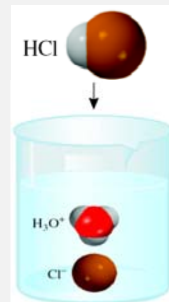
Acids and Bases

Naming Acids

- An ***acid*** can be defined as a substance that yields hydrogen ions (H^+) when dissolved in water.

  For example: HCl gas and HCl in water

  - Pure substance, hydrogen chloride
  - Dissolved in water (H_3O^+ and 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

Naming Compounds

Acids and Bases

Naming Acids

TABLE 2.5 Some Simple Acids

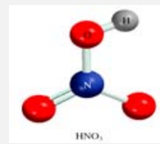
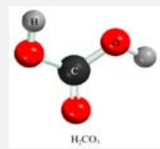
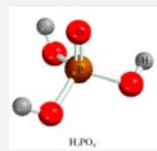
Anion	Corresponding Acid
F^- (fluoride)	HF (hydrofluoric acid)
Cl^- (chloride)	HCl (hydrochloric acid)
Br^- (bromide)	HBr (hydrobromic acid)
I^- (iodide)	HI (hydroiodic acid)
CN^- (cyanide)	HCN (hydrocyanic acid)
S^{2-} (sulfide)	H_2S (hydrosulfuric acid)

Naming Compounds

Acids and Bases

Naming Oxoacids and Oxoanions

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

HNO_3	nitric acid	
H_2CO_3	carbonic acid	
H_3PO_4	phosphoric acid	

Naming Compounds

Acids and Bases

Naming Oxoacids and Oxoanions

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

H_2CO_3	carbonic acid
$HClO_3$	chloric acid
HNO_3	nitric acid
H_3PO_4	phosphoric acid
H_2SO_4	sulfuric acid

Naming Compounds

Acids and Bases

Naming Oxoacids and Oxoanions

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.
   - $HClO_3$ chloric acid
   - $HClO_4$ perchloric acid
2. **Removal of one O atom from the "-ic" acid**: The acid is called "-ous" acid.
   - HNO_3 nitric acid
   - HNO_2 nitrous acid
3. **Removal of two O atoms from the "-ic" acid:** The acid is called "hypo . . . -ous" acid.
   - $HBrO_3$ Bromic acid
   - HBrO hypobromous acid.

Naming Compounds

Naming Oxoacids and Oxoanions

- **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:

- H_3PO_4 phosphoric acid
- $H_2PO_4^-$ dihydrogen phosphate
- HPO_4^{2-} hydrogen phosphate
- PO_4^{3-} phosphate

Naming Compounds

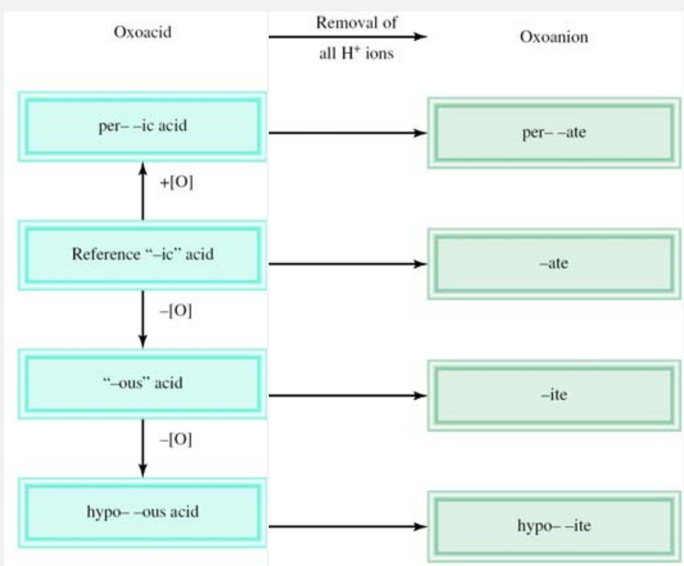
Naming Oxoacids and Oxoanions

TABLE 2.6 Names of Oxoacids and Oxoanions That Contain Chlorine

Acid	Anion
$HClO_4$ (perchloric acid)	ClO_4^- (perchlorate)
$HClO_3$ (chloric acid)	ClO_3^- (chlorate)
$HClO_2$ (chlorous acid)	ClO_2^- (chlorite)
HClO (hypochlorous acid)	ClO^- (hypochlorite)

Naming Compounds

Naming Oxoacids and Oxoanions



Naming Compounds

EXAMPLE 2.9

Name the following oxoacid and oxoanion: (a) H_3PO_3 and (b) IO_4^-.

Strategy To name the acid in (a), we first identify the reference acid, whose name ends with "ic," as shown in Figure 2.15. In (b), we need to convert the anion to its parent acid shown in Table 2.6.

Solution (a) We start with our reference acid, phosphoric acid (H_3PO_4). Because H_3PO_3 has one fewer O atom, it is called phosphorous acid.

(b) The parent acid is HIO_4. Because the acid has one more O atom than our reference iodic acid (HIO_3), it is called periodic acid. Therefore, the anion derived from HIO_4 is called periodate.

Practice Exercise Name the following oxoacid and oxoanion: (a) HBrO and (b) HSO_4^-.

Naming Compounds

Acids and Bases

Naming Bases

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

NaOH	sodium hydroxide
KOH	potassium hydroxide
$Ba(OH)_2$	barium hydroxide

Naming Compounds

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

$BaCl_2{\bullet}2H_2O$	barium chloride dihydrate
$LiCl{\bullet}H_2O$	lithium chloride monohydrate
$MgSO_4{\bullet}7H_2O$	magnesium sulfate heptahydrate
$Sr(NO_3)_2\ {\bullet}4H_2O$	strontium nitrate tetrahydrate

$CuSO_4{\bullet}5H_2O$ →  ← $CuSO_4$

Naming Compounds

Familiar Inorganic Compounds

TABLE 2.7 Common and Systematic Names of Some Compounds

Formula	Common Name	Systematic Name
H_2O	Water	Dihydrogen monoxide
NH_3	Ammonia	Trihydrogen nitride
CO_2	Dry ice	Solid carbon dioxide
NaCl	Table salt	Sodium chloride
N_2O	Laughing gas	Dinitrogen monoxide
$CaCO_3$	Marble, chalk, limestone	Calcium carbonate
CaO	Quicklime	Calcium oxide
$Ca(OH)_2$	Slaked lime	Calcium hydroxide
$NaHCO_3$	Baking soda	Sodium hydrogen carbonate
$Na_2CO_3 \cdot 10H_2O$	Washing soda	Sodium carbonate decahydrate
$MgSO_4 \cdot 7H_2O$	Epsom salt	Magnesium sulfate heptahydrate
$Mg(OH)_2$	Milk of magnesia	Magnesium hydroxide
$CaSO_4 \cdot 2H_2O$	Gypsum	Calcium sulfate dihydrate