Types of Compounds

Compounds generally are one of three types:

Molecular compounds – composed of discrete molecules consisting of certain numbers of atoms (e.g., H_2, H_2O).

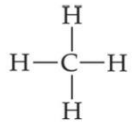
Ionic compounds – composed of electrically neutral numbers of cations (positive ions) and anions (negative ions), but containing no molecules of the compound (e.g., NaCl).

Network solids – composed of infinitely connected neutral atoms in a three-dimensional array, but not containing any discrete molecules (e.g., diamond, SiO_2 – quartz).

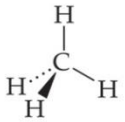
Types of Formulas

- Molecular **formulas give the exact numbers of atoms of each element in a molecule of a compound**.
- Empirical formulas give **the lowest whole-number ratio of atoms** of each element in a compound.
- Example: H_2O_2 = molecular formula,
  HO = empirical formula

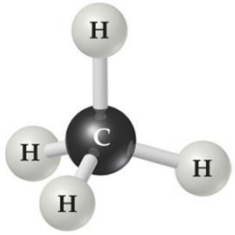
Types of Formulas



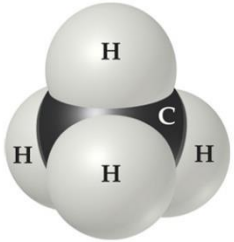
Structural formula



Perspective drawing



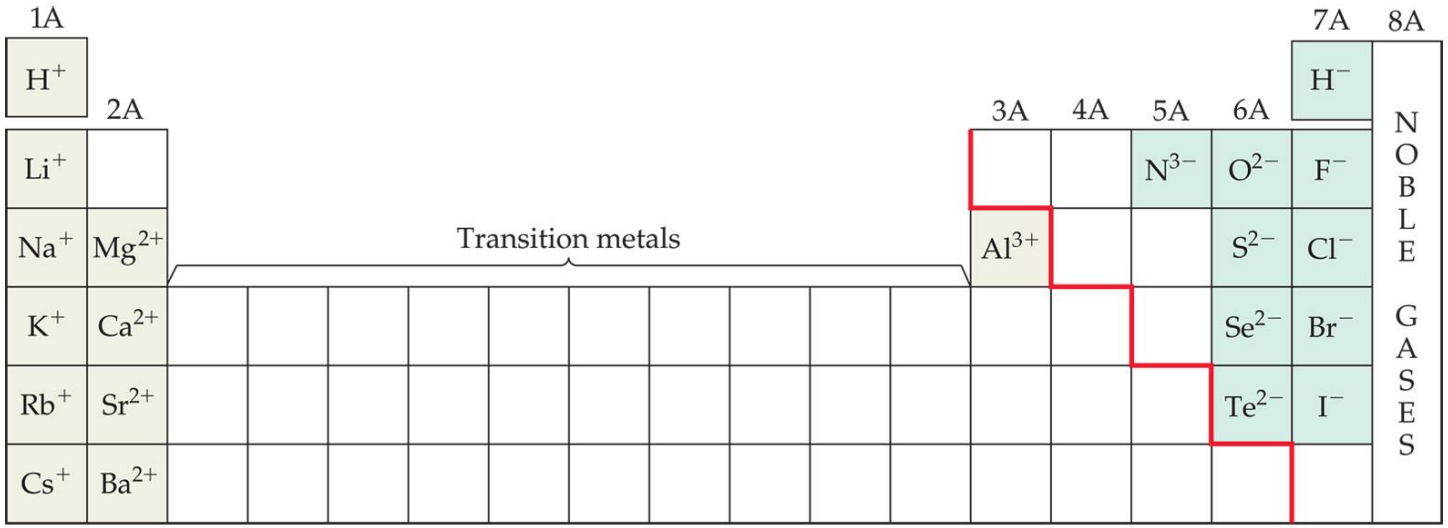
Ball-and-stick model



Space-filling model

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

Ions



- When atoms lose or gain electrons, they become ions.
  - Cations are positive and are generally formed by metals
  - Anions are negative and are formed by nonmetals

“Real Charges” on Ions

- Ions can have only 1, 2 or 3 charges.
- Higher charges that might be assigned are only a formalism (called *oxidation state*).
- Oxidation states greater than +3 or -3 are not real and occur only in molecular compounds.

Polyatomic ions

- The ions that contain more than one atom are called polyatomic ions
- These can be cations or anions

  NH_4^+ , CO_3^{2-}

- Within the polyatomic ion the elements are covalently linked. But they have an overall charge.

1. Polyatomic cations:

   NH_4^+, H_3O^+ and Hg_2^{2+}

2. Anions are many

In most chemical reactions the polyatomic ions will move as a whole.

_____ form ions with a 2^+ charge when they react with nonmetals.

A) Alkali metals

B) Alkaline earth metals

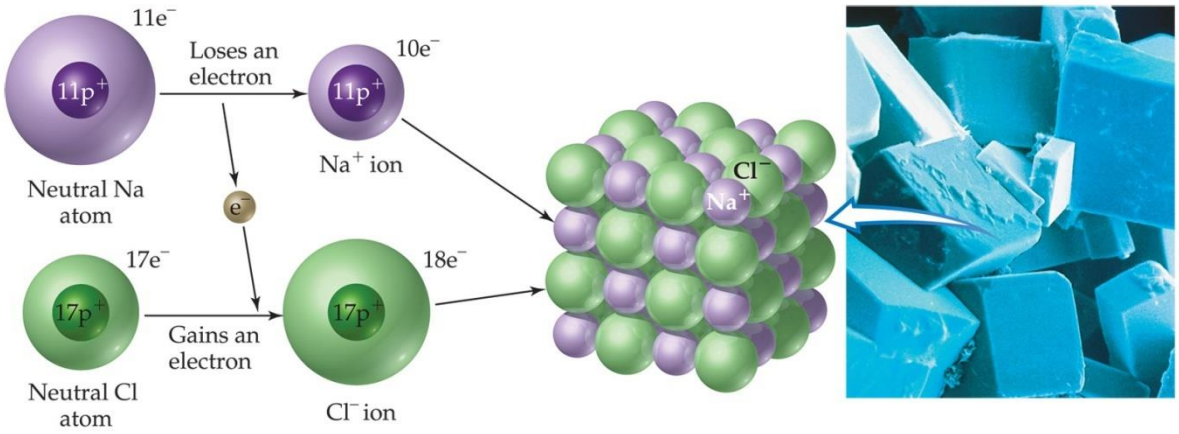
C) Halogens

D) Noble gases

E) None of these choices

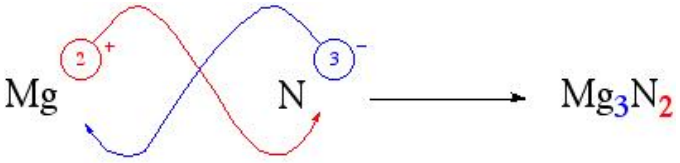
Ionic Bonds

Binary (two element) ionic compounds (such as NaCl) are generally formed between metals and nonmetals.



- All ionic compounds are crystalline solids with a very orderly crystal lattice and have high melting points.
- They are made of electrically equivalent number of cations and anions
- They are referred to with their formula units which is the empirical formula of the compound

Writing Formulas of Ionic Compounds



- Because ionic compounds are electrically neutral, one can determine the formula of a compound this way:
  - The charge on the cation becomes the subscript on the anion.
  - The charge on the anion becomes the subscript on the cation.
  - If these subscripts are not in the lowest whole-number ratio, divide them by the greatest common factor.

Common Cations

Charge	Formula	Name	Formula	Name
1+	**H^+**	**Hydrogen ion**	**NH_4^+**	**Ammonium ion**
	Li^+	Lithium ion	Cu^+	Copper(I) or cuprous ion
	Na^+	**Sodium ion**		
	K^+	**Potassium ion**		
	Cs^+	Cesium ion		
	Ag^+	**Silver ion**		
2+	**Mg^{2+}**	**Magnesium ion**	Co^{2+}	Cobalt(II) or cobaltous ion
	Ca^{2+}	**Calcium ion**	**Cu^{2+}**	**Copper(II)** or cupric ion
	Sr^{2+}	Strontium ion	**Fe^{2+}**	**Iron(II)** or ferrous ion
	Ba^{2+}	Barium ion	Mn^{2+}	Manganese(II) or manganous ion
	Zn^{2+}	**Zinc ion**	Hg_2^{2+}	Mercury(I) or mercurous ion
	Cd^{2+}	Cadmium ion	**Hg^{2+}**	**Mercury(II)** or mercuric ion
			Ni^{2+}	Nickel(II) or nickelous ion
			Pb^{2+}	**Lead(II)** or plumbous ion
			Sn^{2+}	Tin(II) or stannous ion
3+	**Al^{3+}**	**Aluminum ion**	Cr^{3+}	Chromium(III) or chromic ion
			Fe^{3+}	**Iron(III)** or ferric ion

*The most common ions are in boldface.

Common Anions

Charge	Formula	Name	Formula	Name
1−	H^-	Hydride ion	**$C_2H_3O_2^-$**	Acetate ion
	F^-	**Fluoride ion**	ClO_3^-	Chlorate ion
	Cl^-	**Chloride ion**	**ClO_4^-**	**Perchlorate ion**
	Br^-	**Bromide ion**	**NO_3^-**	**Nitrate ion**
	I^-	**Iodide ion**	MnO_4^-	Permanganate ion
	CN^-	Cyanide ion		
	OH^-	**Hydroxide ion**		
2−	**O^{2-}**	**Oxide ion**	**CO_3^{2-}**	**Carbonate ion**
	O_2^{2-}	Peroxide ion	CrO_4^{2-}	Chromate ion
	S^{2-}	**Sulfide ion**	$Cr_2O_7^{2-}$	Dichromate ion
			SO_4^{2-}	**Sulfate ion**
3−	N^{3-}	Nitride ion	**PO_4^{3-}**	**Phosphate ion**

*The most common ions are in boldface.

Inorganic Nomenclature IUPAC system

- Simple ionic compounds are named by the following rules.
- Write the name of the cation first. If a monatomic cation, use its element name (e.g., Ca^{2+} = calcium). If polyatomic, use its usual name (e.g., NH_4^+ = ammonium).
- If the anion is an element, change its ending to *–ide* (e.g., Cl^- = chloride). If the anion is a polyatomic ion, simply write its usual name (e.g., NO_3^- = nitrate).

If the cation can have more than one possible charge, write the charge as a Roman numeral in parentheses.

This happens in the case of transition metals and some heavier main group elements

For example:

Cu^{+} and Cu^{2+} are copper (I) and copper (II)

Fe^{2+} and Fe^{3+} are iron (II) and iron(III)

Some more examples:

Co^{2+} and Co^{3+}

Cr^{2+} and Cr^{3+}

Zn and Ag make only Zn^{2+} and Ag^{+} so their charge does not need to be specified.

When to Use or Not Use Roman Numerals

- $FeCl_3$ is iron (III) chloride
- $CaCl_2$ on the other hand is calcium chloride not calcium (II) chloride as calcium is a main group metal and forms only one cation - Ca^{2+}.

  You do not specify its charge.

Patterns in Oxyanion Nomenclature

- When there are two oxyanions involving the same element:
  - The one with fewer oxygens ends in *-ite*
    - NO_2^- : nitrite; SO_3^{2-} : sulfite
  - The one with more oxygens ends in *-ate*
    - NO_3^- : nitrate; SO_4^{2-} : sulfate

- ClO^- : hypochlorite
  ClO_2^- : chlor*ite*
  ClO_3^- : chlor*ate*
  ClO_4^- : perchlorate

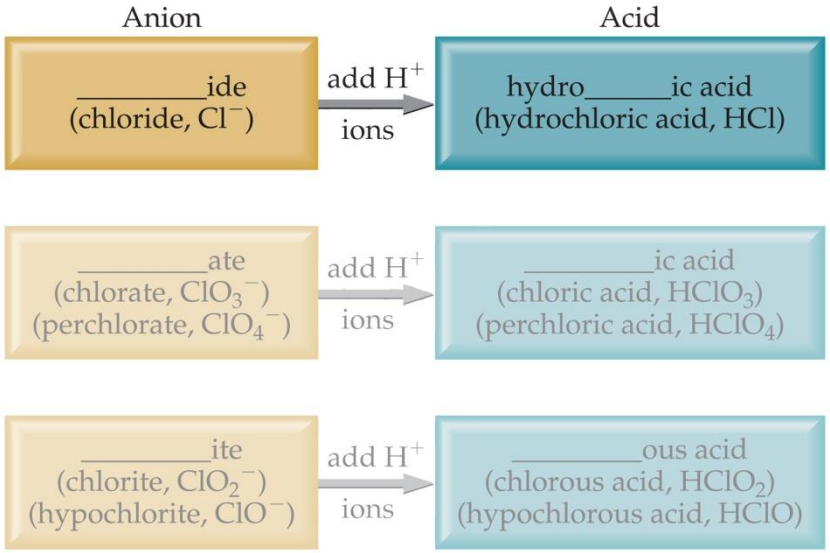
Anions derived by adding H^+ to the oxy anion:

- CO_3^{2-} and HCO_3^-

  Carbonate and hydrogen carbonate
- PO_4^{3-} , $H_2PO_4^-$

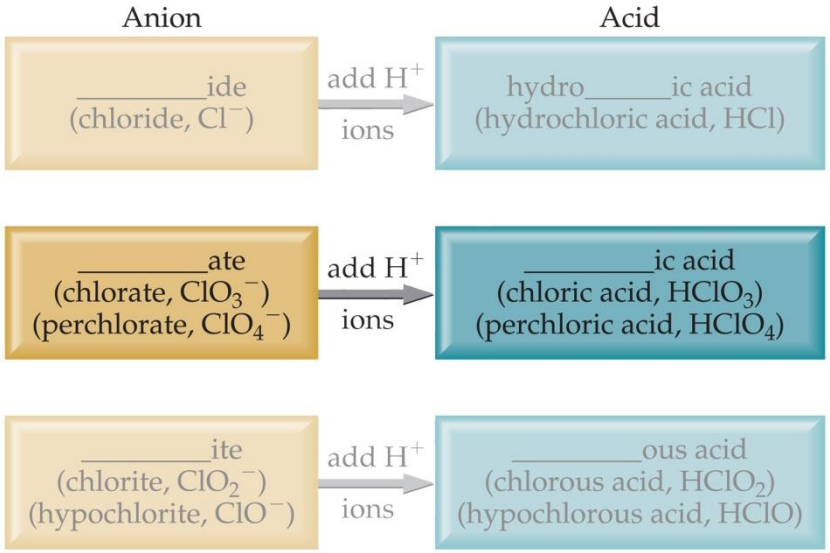
  Phosphate and *di*hydrogen phosphate

Acid Nomenclature



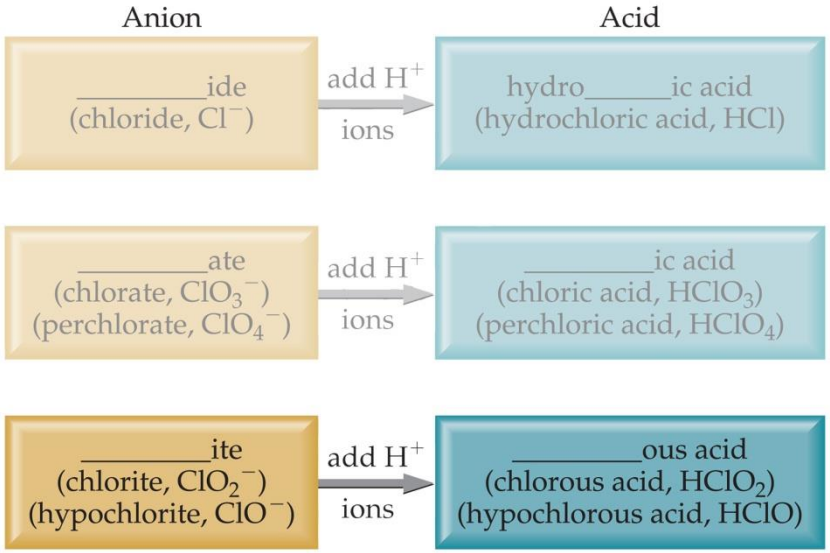
- If the anion in the acid ends in *-ide*, change the ending to *-ic acid* and add the prefix *hydro-* :
  - HCl: hydrochloric acid
  - HBr: hydrobromic acid
  - HI: hydroiodic acid

Acid Nomenclature



- If the anion in the acid ends in -*ate*, change the ending to -*ic acid:*
  - $HClO_3$: chloric acid
  - $HClO_4$: perchloric acid

Acid Nomenclature



- If the anion in the acid ends in -*ite*, change the ending to -*ous acid*:
  - HClO: hypochlorous acid
  - $HClO_2$: chlorous acid

TABLE 4.2 Common Strong Acids and Bases

Strong Acids	Strong Bases
Hydrochloric, HCl	Group 1A metal hydroxides (LiOH, NaOH, KOH, RbOH, CsOH)
Hydrobromic, HBr	Heavy group 2A metal hydroxides [$Ca(OH)_2$, $Sr(OH)_2$, $Ba(OH)_2$]
Hydroiodic, HI	
Chloric, $HClO_3$	
Perchloric, $HClO_4$	
Nitric, HNO_3	
Sulfuric, H_2SO_4	

Other than this you need to know the names and formulas of:

- Acetic acid, CH_3COOH
- Phosphoric acid, H_3PO_4
- Sulfurous acid H_2SO_3
- Hydrosulfuric acid H_2S
- Carbonic acid H_2CO_3
- Chlorous acid $HClO_2$
- Hypochlorous acid HClO ……for now

When a metal and a nonmetal react, the _____ tends to lose electrons and the _____

tends to gain electrons.

A) metal, nonmetal

B) nonmetal, metal

C) nonmetal, nonmetal

D) metal, metal

E) None of the above, these elements share electrons .

Give the IUPAC names of the following:

• NH_4Br	• Ammonium bromide
• Cr_2O_3	• Chromium (III) oxide
• $Co(NO_3)_2$	• Cobalt (II) nitrate
• $ZnSO_4$	• Zinc Sulfate
• Ag_2SO_4	• Silver sulfate
• K_2CrO_4	• Potassium chromate

Covalent or Molecular Compounds

- Covalent compounds are formed between two nonmetals.
- In covalent compounds the elements share electrons.
- These are true molecules
- Covalent compounds can be solids, liquids or gases at room temperature.

Nomenclature of Covalent Compounds

Prefix	*Meaning*
Mono-	*1*
Di-	*2*
Tri-	*3*
Tetra-	*4*
Penta-	*5*
Hexa-	*6*
Hepta-	*7*
Octa-	*8*
Nona-	*9*
Deca-	*10*

- The less electronegative atom is usually listed first.
- A prefix is used to denote the number of atoms of each element in the compound (*mono*- is not used on the first element listed, however.)

Nomenclature of Covalent Compounds

Prefix	*Meaning*
Mono-	*1*
Di-	*2*
Tri-	*3*
Tetra-	*4*
Penta-	*5*
Hexa-	*6*
Hepta-	*7*
Octa-	*8*
Nona-	*9*
Deca-	*10*

- The ending on the more electronegative element is changed to *-ide.*

  - CO_2: carbon dioxide
  - CCl_4: carbon tetrachloride

Nomenclature of Covalent Compounds

Prefix	*Meaning*
Mono-	*1*
Di-	*2*
Tri-	*3*
Tetra-	*4*
Penta-	*5*
Hexa-	*6*
Hepta-	*7*
Octa-	*8*
Nona-	*9*
Deca-	*10*

If the prefix ends with *a* or *o* and the name of the element begins with a vowel, the two successive vowels are often elided into one:

N_2O_5: dinitrogen pentoxide

- XeO_3
- Dinitrogen tetroxide
- Hydrogen cyanide

- Xenon trioxide
- N_2O_4
- HCN

The correct name for N_2O_5 is _____.

A) nitric oxide

B) nitrogen pentoxide

C) nitrogen oxide

D) nitrous oxide

E) dinitrogen pentoxide

The correct name for CaH_2 is

A) calcium hydride
B) hydrocalcium
C) calcium dihydride
D) Cacium (II) hydride

- Some compounds are still known by their common names
- H_2O - water
- NH_3 - ammonia
- H_2O_2 -hydrogen peroxide
- H_2S - hydrogen sulfide
- CH_4 - methane
- C_2H_6 - ethane
- CH_3OH - methanol
- C_2H_5OH - ethanol