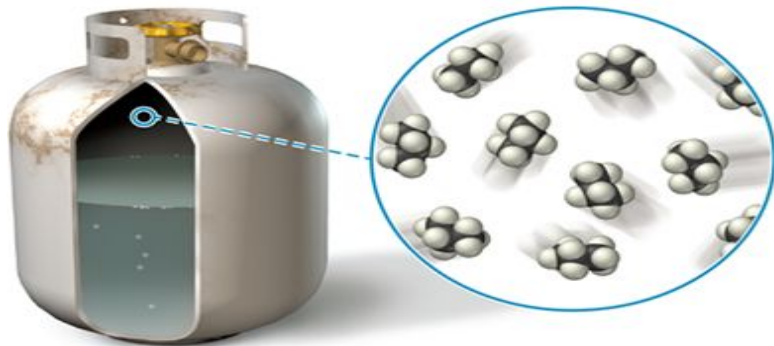


Ionic Compounds

- **Ionic compounds** are composed of cations (usually a metal) and anions (usually one or more nonmetals) bound together by ionic bonds.
- The basic unit of an ionic compound is the **formula unit**, the smallest, electrically neutral collection of ions.
- **Table salt** is an ionic compound with the formula unit NaCl, which is composed of Na^+ and Cl^- ions in a one-to-one ratio.

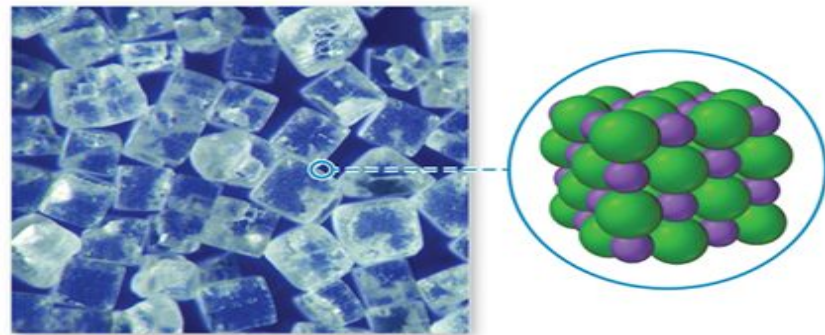
Molecular and Ionic Compounds

A Molecular Compound



(a)

An Ionic Compound



(b)

Ionic Compounds: Formulas and Names (1 of 2)

- **Summarizing Ionic Compound Formulas**

- Ionic compounds always contain positive and negative ions.
- In a chemical formula, the sum of the charges of the cations must equal the sum of the charges of the anions.
- The formula of an ionic compound reflects the smallest whole-number ratio of ions.

Ionic Compounds: Formulas and Names

(2 of 2)

- The charges of the representative elements can be predicted from their group numbers.
- The representative elements form only one type of charge.
- Transition metals tend to form multiple types of charges.
- Hence, their charges cannot be predicted as in the case of most representative elements.

Naming Ionic Compounds

- Ionic compounds can be categorized into two types, depending on the metal in the compound.



Naming Type I Ionic Compounds

- Type I ionic compounds contain a metal whose charge is invariant from one compound to another when bonded with a nonmetal anion.
- The metal ion always has the same charge.

Metals Whose Charge Is Invariant from One Compound to Another

Metals Whose Charge Is Invariant from One Compound to Another

	1A 1	2A 2											3A 13	4A 14	5A 15	6A 16	7A 17	8A 18	
1	1 H																		2 He
2	3 Li 1+	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne	
3	11 Na 1+	12 Mg 2+	3B 3	4B 4	5B 5	6B 6	7B 7	8 8	8B 9	10 10	1B 11	2B 12	13 Al 3+	14 Si	15 P	16 S	17 Cl	18 Ar	
4	19 K 1+	20 Ca 2+	21 Sc 3+	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn 2+	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr	
5	37 Rb 1+	38 Sr 2+	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag 1+	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe	
6	55 Cs 1+	56 Ba 2+	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	
7	87 Fr	88 Ra	89 Ac	104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Ds	111 Rg	112 Cn	113 Nh	114 Fl	115 Mc	116 Lv	117 Ts	118 Og	

Conceptual Connection 3.6 (1 of 2)

Which metal has the same charge in all of its compounds?

- a. Fe
- b. Mo
- c. Pb
- d. Sr

Conceptual Connection 3.6 (2 of 2)

Which metal has the same charge in all of its compounds?

a. Fe

b. Mo

c. Pb

d. Sr

Table 3.2 Some Common Monoatomic Anions

Nonmetal	Symbol for Ion	Base Name	Anion Name
Fluorine	F ⁻	fluor	Fluoride
Chlorine	Cl ⁻	chlor	Chloride
Bromine	Br ⁻	brom	Bromide
Iodine	I ⁻	iod	Iodide
Oxygen	O ²⁻	ox	Oxide
Sulfur	S ²⁻	sulf	Sulfide
Nitrogen	N ³⁻	nitr	Nitride
Phosphorus	P ³⁻	phosph	Phosphide

Naming Binary Ionic Compounds of Type One Cations

- **Binary compounds** contain only two different elements. The names of binary ionic compounds take the following form:

**name of
cation
(metal)**

**base name of
anion (nonmetal)
+ *-ide***

Examples: Type One Binary Ionic Compounds

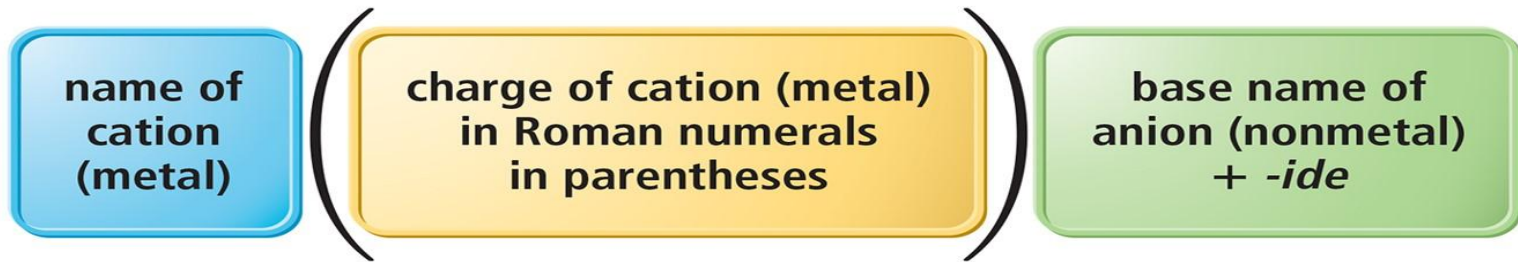
- The name for KCl consists of the name of the cation, **potassium**, followed by the base name of the anion, **chlor**, with the ending **-ide**.
 - KCl is **potassium chloride**.
- The name for CaO consists of the name of the cation, **calcium**, followed by the base name of the anion, **ox**, with the ending **-ide**.
 - CaO is **calcium oxide**.

Naming Type II Ionic Compounds

- The second type of ionic compound contains a metal that can form more than one kind of cation, depending on the compound, bonded to a nonmetal anion.
- Metals of this type are often **transition metals**.
- The metal's charge must be specified for a given compound.
- The proportion of metal cation to nonmetal anion helps us determine the charge on the metal ion.

Naming Type II Binary Ionic Compounds (1 of 2)

- The full name of compounds containing metals that form more than one kind of cation have the following form:



- The charge of the metal cation can be determined by inference from the sum of the charges of the nonmetal.

Type II Ionic Compounds

- Iron, for instance, forms a 2+ cation in some of its compounds and a 3+ cation in others.
 - FeS: here, the iron cation has +2 charge (Fe²⁺).
 - Fe₂S₃ : here, the iron cation has +2 charge (Fe³⁺).
 - CrBr₃ : here, the chromium cation has +3 charge (Cr³⁺).
 - CuO: here, the copper cation has +2 charge (Cu²⁺).
- Some main group metals, such as Pb, Ti, and Sn, form more than one type of cation.

Naming Type II Binary Ionic Compounds (2 of 2)

- For these types of metals, the name of the cation is followed by a roman numeral (in parentheses) that indicates the charge of the metal in that particular compound.
 - For example, we distinguish between Fe^{2+} and Fe^{3+} as follows:
 - Fe^{2+} Iron(II)
 - Fe^{3+} Iron(III)

Table 3.3 Some Metals That Form Cations with Different Charges (1 of 2)

Metal	Ion	Name	Older Name*
Chromium	Cr ²⁺ Cr ³⁺	Chromium(II) Chromium(III)	Chromous Chromic
Iron	Fe ²⁺ Fe ³⁺	Iron(II) Iron(III)	Ferrous Ferric
Cobalt	Co ²⁺ Co ³⁺	Cobalt(II) Cobalt(III)	Cobaltous Cobaltic
Copper	Cu ⁺ Cu ²⁺	Copper(I) Copper(II)	Cuprous Cupric
Tin	Sn ²⁺ Sn ⁴⁺	Tin(II) Tin(IV)	Stannous Stannic
Mercury	Hg ₂ ²⁺ Hg ²⁺	Mercury(I) Mercury(II)	Mercurous Mercuric
Lead	Pb ²⁺ Pb ⁴⁺	Lead(II) Lead(IV)	Plumbous Plumbic

Table 3.3 Some Metals That Form Cations with Different Charges (2 of 2)

*An older naming system substitutes the names found in this column for the name of the metal and its

charge. Under this system, chromium

(II)

oxide is named chromous oxide. Additionally, the suffix

-ous indicates the ion with the lesser charge, and **-ic** indicates the ion with the greater charge. We will

not use the older system in this text.

Example: Type II Binary Ionic Compounds

- To name CrBr_3 , determine the charge on the chromium.
 - Total charge on cation + total anion charge = 0.
 - Cr charge + 3 (Br⁻ charge) = 0.
 - Since each Br has a -1 charge, then:
 - Cr charge + 3(-1) = 0.
 - Cr charge - 3 = 0.
 - Cr = +3.
 - Hence, the cation Cr^{3+} is called chromium(III), while Br⁻ is called bromide.
- Therefore, CrBr_3 is **chromium(III) bromide**.

Polyatomic Ions

- Many common ionic compounds contain ions that are themselves composed of a group of covalently bonded atoms with an overall charge.
- This group of charged species is called polyatomic ions.
 - NaNO_3 contains Na^+ and NO_3^- .
 - CaCO_3 contains Ca^{2+} and CO_3^{2-} .
 - $\text{Mg}(\text{ClO}_3)_2$ contains Mg^{2+} and ClO_3^- .

Naming Ionic Compounds Containing Polyatomic Ions

- We name ionic compounds that contain a polyatomic ion in the same way as other ionic compounds, except that we use the name of the polyatomic ion whenever it occurs.
- For example, NaNO_2 is named according to its cation, Na^+ , **sodium**, and its polyatomic anion, NO_2^- , **nitrite**.
- Hence, NaNO_2 is **sodium nitrite**.

Table 3.4 Some Common Polyatomic Ions

Name	Formula
Acetate	$\text{C}_2\text{H}_3\text{O}_2^-$
Carbonate	CO_3^{2-}
Hydrogen carbonate (or bicarbonate)	HCO_3^-
Hydroxide	OH^-
Nitrite	NO_2^-
Nitrate	NO_3^-
Chromate	CrO_4^{2-}
Dichromate	$\text{Cr}_2\text{O}_7^{2-}$
Phosphate	PO_4^{3-}
Hydrogen phosphate	HPO_4^{2-}
Dihydrogen phosphate	H_2PO_4^-
Ammonium	NH_4^+

Name	Formula
Hypochlorite	ClO^-
Chlorite	ClO_2^-
Chlorate	ClO_3^-
Perchlorate	ClO_4^-
Permanganate	MnO_4^-
Sulfite	SO_3^{2-}
Hydrogen sulfite (or bisulfite)	HSO_3^-
Sulfate	SO_4^{2-}
Hydrogen sulfate (or bisulfate)	HSO_4^-
Cyanide	CN^-
Peroxide	O_2^{2-}

Oxyanions (1 of 2)

- Most polyatomic ions are **oxyanions**, anions containing oxygen and another element.
- Notice that when a series of oxyanions contains different numbers of oxygen atoms, they are named according to the number of oxygen atoms in the ion.
- If there are two ions in the series,
 - the one with more oxygen atoms has the ending **-ate**, and
 - the one with fewer has the ending **-ite**.
- For example,
 - NO_3^- is **nitrate**.
 - SO_4^{2-} is **sulfate**.
 - NO_2^- is **nitrite**.
 - SO_3^{2-} is **sulfite**.

Oxyanions (2 of 2)

- If there are more than two ions in the series, then the prefixes **hypo-**, meaning **less than**, and **per-**, meaning **more than**, are used.
- Oxyanions of an element in the same group will have the same formulas and naming except for the element's root name.

ClO^- **hypochlorite**

ClO_2^- **chlorite**

ClO_3^- **chlorate**

ClO_4^- **perchlorate**

BrO^- **hypobromite**

BrO_2^- **bromite**

BrO_3^- **bromate**

BrO_4^- **perbromate**

Conceptual Connection 3.7 (1 of 2)

Identify the polyatomic ion and its charge in each compound:

KNO_2 , CaSO_4 , $\text{Mg}(\text{NO}_3)_2$.

- a. NO_2^- , SO_4^{2-} , and NO_3^-
- b. K^+ , Ca^{2+} , and Mg^{2+}
- c. K^+ , Ca^{2+} , Mg^{2+} , NO_2^- , SO_4^{2-} , and NO_3^-
- d. NO_2^{2-} , SO_4^- , and NO_3^{2-}

Conceptual Connection 3.7 (2 of 2)

Identify the polyatomic ion and its charge in each compound:

KNO_2 , CaSO_4 , $\text{Mg}(\text{NO}_3)_2$.

- a. NO_2^- , SO_4^{2-} , and NO_3^-
- b. K^+ , Ca^{2+} , and Mg^{2+}
- c. K^+ , Ca^{2+} , Mg^{2+} , NO_2^- , SO_4^{2-} , and NO_3^-
- d. NO_2^{2-} , SO_4^- , and NO_3^{2-}

Hydrated Ionic Compounds

- **Hydrates** are ionic compounds containing a specific number of water molecules associated with each formula unit.
 - For example, the formula for epsom salts is
 $\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$.
 - Its systematic name is magnesium sulfate heptahydrate.
 - $\text{CoCl}_2 \cdot 6\text{H}_2\text{O}$ is cobalt(II) chloride hexahydrate.

Common Hydrate Prefixes

- Common hydrate prefixes

hemi = $\frac{1}{2}$

mono = 1

di = 2

tri = 3

tetra = 4

penta = 5

hexa = 6

hepta = 7

octa = 8

- Other common hydrated ionic compounds and their names are as follows:
 - $\text{CaSO}_4 \cdot \frac{1}{2} \text{H}_2\text{O}$ is called calcium sulfate hemihydrate.
 - $\text{BaCl}_2 \cdot 6\text{H}_2\text{O}$ is called barium chloride hexahydrate.
 - $\text{CuSO}_4 \cdot 6\text{H}_2\text{O}$ is called copper sulfate hexahydrate.