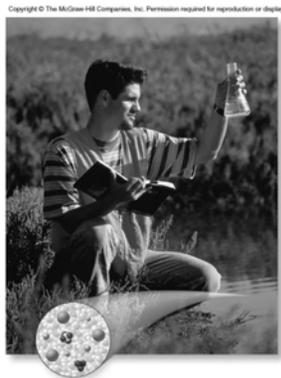


Chapter 3

Chemical Compounds



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Chapter 3 Topics

1. Ionic and Molecular Compounds
2. Monatomic and Polyatomic Ions
3. Formulas for Ionic Compounds
4. Naming Ionic Compounds
5. Naming and Writing Formulas for Molecular Compounds
6. Acids and Bases
7. Predicting Properties and Naming Compounds

2

Water is part of the earth, ocean, rivers, and atmosphere.

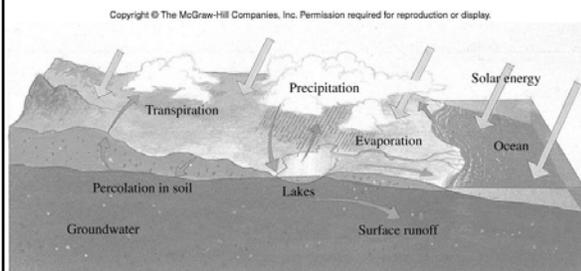
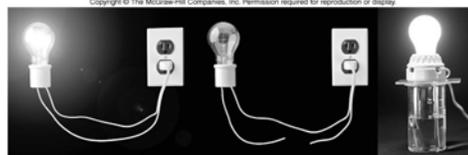


Figure 3.02

3

How does water conduct electricity?

- Water conducts electricity because it contains ions. When compounds containing ions dissolve in water, the ions exist separate from each other. The mobility of ions allows for a current to pass through water.



A Circuit complete

B Circuit not complete

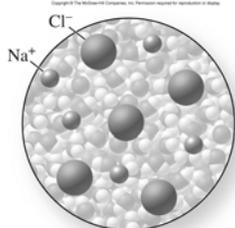
C Circuit complete

Figure 3.03

4

Electrolytes

- Solutions containing ions are electrolytes.
- Sodium chloride dissolved in water is an electrolyte.



Dissolve

5

Compound Names and Classifications

- $\text{CH}_3\text{CO}_2\text{H}$ – acetic acid, acid
- HCl – hydrochloric acid, acid
- HNO_3 – nitric acid, acid
- NaCl – sodium chloride, ionic compound
- CH_3OH – methanol, molecular compound

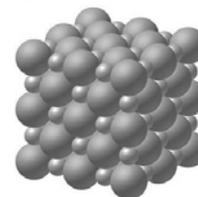
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Ionic and Molecular Compounds

- An ionic compound consists of oppositely charged cations and anions. Usually the cation is a metal and the anion is a nonmetal or a group of nonmetals. (ie, NaCl)
- A molecular compound consists of two or more different nonmetals. It exists as a discrete unit of atoms. (ie, CO₂)

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- NaCl is an ionic compound
- CO₂ is a molecular compound
- O₂ is a molecular element



A NaCl



B CO₂



C O₂

Figure 3.07

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Identifying Ionic and Molecular Compounds

Identify each compound as ionic or molecular.

- CCl₄
- CaF₂
- SF₆
- CuCO₃
- H₂O

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Identifying Ionic and Molecular Compounds

Identify each compound as ionic or molecular.

- CCl₄
- CaF₂
- SF₆
- CuCO₃
- H₂O

classify

10

When an ionic compound dissolves in water, it dissociates into its ions.

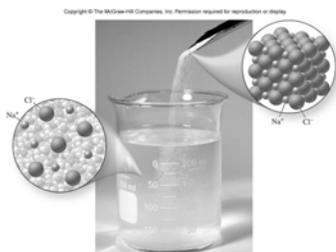
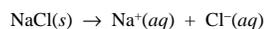
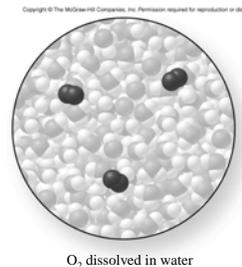


Figure 3.08

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Most molecular substances do not dissociate in water.

- Most molecular substances, such as CH₃OH or O₂, do not dissociate into ions in aqueous solution. The molecules remain intact.
- CH₃OH(l) → CH₃OH(aq)
- O₂(g) → O₂(aq)



O₂ dissolved in water

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3.2 Monatomic and Polyatomic Ions

- In Chapter 2 we saw that we can predict charges on some monatomic ions from their positions in the periodic table.
- Look at the names of ions listed. Do you notice any patterns in their names?

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TABLE 3.2 Common Monatomic Ions

Ion	Name of Ion	Ion	Name of Ion	Ion	Name of Ion
O ²⁻	oxide ion	Al ³⁺	aluminum ion	K ⁺	potassium ion
Na ⁺	sodium ion	Mg ²⁺	magnesium ion	F ⁻	fluoride ion
N ³⁻	nitride ion	Cl ⁻	chloride ion		

Common Monatomic Ions

You must know the charges for all these ions.

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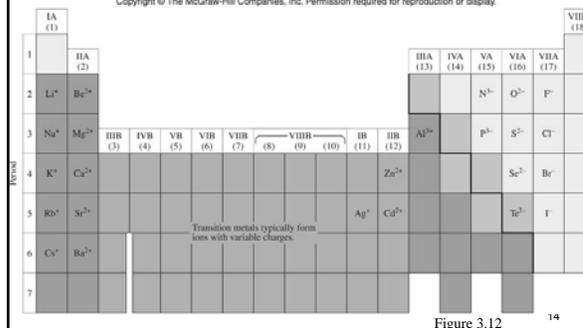


Figure 3.12

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Polyatomic Ions

- A polyatomic ion consists of a group of atoms with an overall net charge.
- These two are also called **oxoanions** because they contain oxygen attached to some other element.

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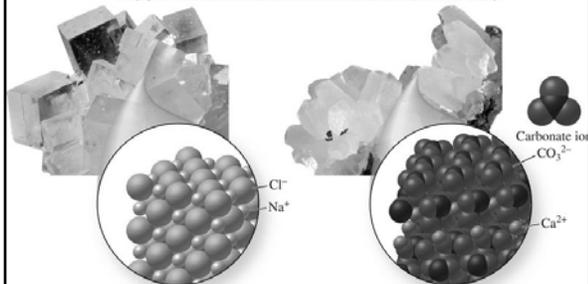
Ionic Compounds with Polyatomic Ions

- Many ionic compounds contain a polyatomic anion:
 - CaCO₃, calcium carbonate
 - NaHCO₃, sodium bicarbonate
 - NaCN, sodium cyanide
 - KNO₃, potassium nitrate
- The only common polyatomic cation is the ammonium ion, NH₄⁺:
 - NH₄NO₃, ammonium nitrate

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Ionic Compounds

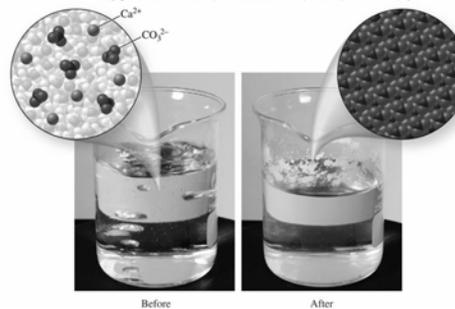
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Calcium carbonate is dissolved in hard water:

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Naming Polyatomic Ions

- The name of the oxoanion ion changes when the number of oxygen atoms bonded to the central atom changes. Can you see any patterns?

TABLE 3.3 Common Oxoanions

Formula of Ion	Name of Ion
NO_3^-	nitrate ion
NO_2^-	nitrite ion
SO_4^{2-}	sulfate ion
SO_3^{2-}	sulfite ion

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Trends for Polyatomic Ions

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B BO_3^{3-} borate	C CO_3^{2-} carbonate	N N^{3-} nitride NO_3^- nitrate NO_2^- nitrite	O O^{2-} oxide O_2^{2-} peroxide	F F^- fluoride No oxoanions
	Si SiO_4^{4-} silicate	P P^{3-} phosphide PO_4^{3-} phosphate PO_3^{3-} phosphite	S S^{2-} sulfide SO_4^{2-} sulfate SO_3^{2-} sulfite	Cl Cl^- chloride ClO_4^- perchlorate ClO_3^- chlorate ClO_2^- chlorite ClO^- hypochlorite
		As As^{3-} arsenide AsO_4^{3-} arsenate AsO_3^{3-} arsenite	Se Se^{2-} selenide SeO_4^{2-} selenate SeO_3^{2-} selenite	Br Br^- bromide BrO_4^- perbromate BrO_3^- bromate BrO_2^- bromite BrO^- hypobromite
			Te TeO_4^{2-} tellurate TeO_3^{2-} tellurite	I I^- iodide IO_4^- periodate IO_3^- iodate IO_2^- iodite IO^- hypoiodite

Figure 3.17

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These are the ions listed on your in-class handout. You must memorize the ones in bold on the handout.

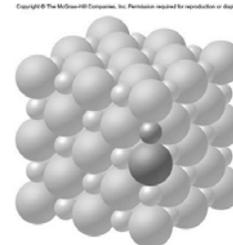
TABLE 3.4 Important Polyatomic Ions

1- Ions		2- Ions	
nitrate	NO_3^-	chromate	CrO_4^{2-}
nitrite	NO_2^-	dichromate	$\text{Cr}_2\text{O}_7^{2-}$
bicarbonate (hydrogen carbonate)	HCO_3^-	sulfate	SO_4^{2-}
perchlorate	ClO_4^-	sulfite	SO_3^{2-}
chlorate	ClO_3^-	carbonate	CO_3^{2-}
chlorite	ClO_2^-	oxalate	$\text{C}_2\text{O}_4^{2-}$
hypochlorite	ClO^-	peroxide	O_2^{2-}
cyanide	CN^-	3- Ions	
hydroxide	OH^-	phosphate	PO_4^{3-}
acetate	CH_3CO_2^-	phosphite	PO_3^{3-}
permanganate	MnO_4^-	borate	BO_3^{3-}
		1+ Ion	
		ammonium	NH_4^+

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3.3 Formulas for Ionic Compounds

- An ionic compound has no overall charge, so the charges on the cations and anions must cancel one another. This is the case in a pure substance, or when it is dissolved.
- The formula that shows this ratio with the smallest whole numbers is called its formula unit.



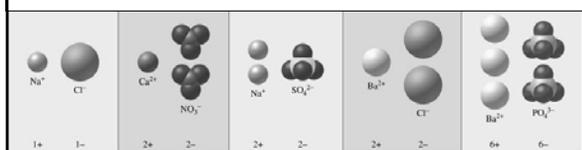
NaCl

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Writing Ionic Formulas

- Write the formula for the compound that contains each set of ions in the ratio given.

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Writing Ionic Formulas (Like Example 3.6)

- Write the formulas for compounds containing the following ions:
 - calcium ion and fluoride ion
 - aluminum ion and oxide ion
 - sodium ion and sulfate ion
 - sodium ion and sulfite ion
 - ammonium ion and phosphate ion
 - lithium ion and nitrate ion

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3.4 Naming Simple Ionic Compounds

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TABLE 3.5 Names of Some Ionic Compounds

Formula	Name	Formula	Name
NaCl	sodium chloride	Mg(NO ₃) ₂	magnesium nitrate
NaNO ₂	sodium nitrite	BaO	barium oxide
MgCl ₂	magnesium chloride	Li ₃ N	lithium nitride

Notice that all the metals are cations with charges that we could predict from the name of the compound they are in.

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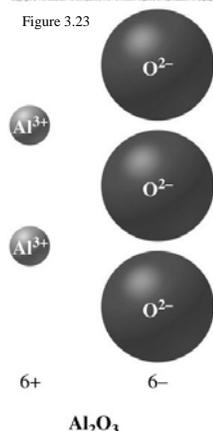
Common Monatomic Ions

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Figure 3.23

- What is the name of this compound?



Al_2O_3

Naming Ionic Compounds Containing Metals with Variable Charges

- Many metals, including most of the transition metals, can form more than one type of ion. When these metals are present in ionic compounds, an additional component must be added to the name to distinguish between similar compounds.
- How can we distinguish between CuO and Cu₂O?
- What is the difference between them?
- Why do they combine in different ratios?

ion diff

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What are the rules for naming these compounds?

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TABLE 3.6 Ionic Compounds Containing Metals with Various Charges

Compound	Cation	Systematic Name
FeCl ₂	Fe ²⁺	iron(II) chloride
FeCl ₃	Fe ³⁺	iron(III) chloride
Cu ₂ O	Cu ⁺	copper(I) oxide
CuO	Cu ²⁺	copper(II) oxide
CuSO ₄	Cu ²⁺	copper(II) sulfate
SnO	Sn ²⁺	tin(II) oxide

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Some (not all) Charges for Metals that can have Ions of More than One Charge

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Figure 3.25

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Naming Ionic Compounds when Roman Numerals are Needed

- Name the following compounds
 - MnO
 - MnO₂
 - CuSO₄
 - CrO₃
 - Fe(NO₃)₃

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Older Method for Naming...

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TABLE 3.7 Names of Some Ionic Compounds Composed of Metals with Variable Charges

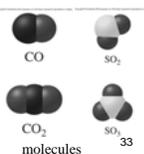
Compound	Ion	Stock Name	Old Name
FeCl ₂	Fe ²⁺	iron(II) chloride	ferrous chloride
FeCl ₃	Fe ³⁺	iron(III) chloride	ferric chloride
Cu ₂ O	Cu ⁺	copper(I) oxide	cuprous oxide
CuO	Cu ²⁺	copper(II) oxide	cupric oxide
SnO	Sn ²⁺	tin(II) oxide	stannous oxide
SnO ₂	Sn ⁴⁺	tin(IV) oxide	stannic oxide

You do not have to know how to use this method.

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3.5 Naming and Writing Formulas for Molecular Compounds

- Because molecular compounds do not consist of ions, the nonmetals that compose them are in ratios that are difficult to predict.
- Also, there are sometimes many different compounds composed of the same elements but just in different ratios or different number of atoms per molecule:
- CO, CO₂
- SO₂, SO₃
- NO, NO₂, NO₃, N₂O, N₂O₄, N₂O₅



Naming Molecular Compounds

- Look at the formulas and the names of the molecular compounds below. Can you determine the rules for naming them?

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TABLE 3.8 Names of Some Common Molecular Compounds

Formula	Name	Formula	Name
CO	carbon monoxide	SO ₃	sulfur trioxide
CO ₂	carbon dioxide	N ₂ O ₄	dinitrogen tetroxide
CCl ₄	carbon tetrachloride	PF ₅	phosphorus pentafluoride

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Prefixes used for Naming Molecular Compounds

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TABLE 3.9 Common Greek Prefixes

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

- The mono prefix is not used for the first element in the compound.
- The mono prefix is not used for the second element when there are no other compounds with the same combination of the elements.

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Naming Molecular Compounds

- Name the following compounds:

- SO₃
- SF₆
- N₂O₄
- CO
- PCl₅

name

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Nonsystematic for Molecular Compounds (know these)

- Water – H_2O
- Ammonia – NH_3
- Hydrogen peroxide – H_2O_2

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3.6 Acids and Bases

- Acids and bases exist as ions when dissolved in water. Many bases are ionic compounds, but acids are not – they are molecular compounds. How do acids form ions in solution when they are not composed of ions?
- Acids form ions as a result of their interaction with water: $\text{HCl}(g) \rightarrow \text{H}^+(aq) + \text{Cl}^-(aq)$
- The $\text{H}^+(aq)$ that forms actually exists as $\text{H}_3\text{O}^+(aq)$.

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Ionization of HCl in Water

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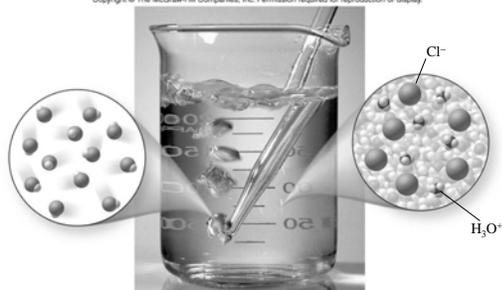


Figure 3.30 39

Bases ionize in water to form OH^- ions

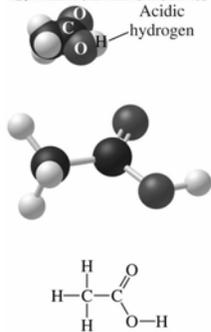
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Figure 3.33 40

Oxoacids

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Acidic H

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Naming Binary Acids

- How are the first four acids similar and how are they named?

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Formula	Name	Formula	Name
$\text{HF}(aq)$	hydrofluoric acid	$\text{H}_2\text{SO}_4(aq)$	sulfuric acid
$\text{HCl}(aq)$	hydrochloric acid	$\text{H}_2\text{SO}_3(aq)$	sulfurous acid
$\text{HI}(aq)$	hydroiodic acid	$\text{HClO}_4(aq)$	perchloric acid
$\text{H}_2\text{S}(aq)$	hydrosulfuric acid	$\text{HClO}_3(aq)$	chloric acid
$\text{H}_2\text{CO}_3(aq)$	carbonic acid	$\text{HClO}_2(aq)$	chlorous acid
$\text{HNO}_3(aq)$	nitric acid	$\text{HClO}(aq)$	hypochlorous acid

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Naming Binary Acids

- Why do some of the oxoacids have an -ic suffix while others have an -ous suffix? How can you predict the suffix?

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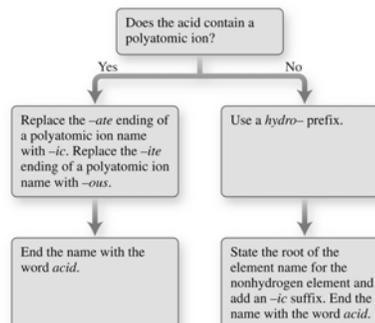
TABLE 3.11 Names of Some Common Acids

Formula	Name	Formula	Name
HF(aq)	hydrofluoric acid	H ₂ SO ₄ (aq)	sulfuric acid
HCl(aq)	hydrochloric acid	H ₂ SO ₃ (aq)	sulfurous acid
HI(aq)	hydroiodic acid	HClO ₄ (aq)	perchloric acid
H ₂ S(aq)	hydrosulfuric acid	HClO ₃ (aq)	chloric acid
H ₂ CO ₃ (aq)	carbonic acid	HClO ₂ (aq)	chlorous acid
HNO ₃ (aq)	nitric acid	HClO(aq)	hypochlorous acid

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Naming Acids

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Naming acids

- Name the following acids:
 - HCl(aq)
 - HNO₃(aq)
 - HNO₂(aq)
 - H₂SO₄(aq)

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3.7 Predicting Properties and Naming Compounds

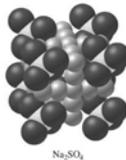
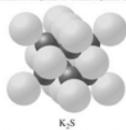
- Before naming a compound, you must first classify it as either an ionic compound, molecular compound, or acid.
 - If it is an ionic compound, you must also decide if the cation is an ion that can vary in charge.
- These classifications allow you to name the compound with the proper rules.

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Naming

- Classify and then name these compounds

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Naming Compounds

- Classify and then name the following:
 - NO₂
 - Mg₃N₂
 - CaSO₄
 - H₃PO₄(aq)
 - FeCl₃
 - Which of these does not form ions when dissolved in water?
 - Which of these is most likely a gas at room temperature?
 - Which of these is an electrolyte?

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