Chemistry 151: Basic Chemistry

Chapter 4 (Section 4.3): Nomenclature

Time For a (*relevant*) Joke!

Two chemists walk into a bar.
The first chemist says, "I'll have some H Two O"
i.e. H_2O, water
A clear liquid in a glass arrives...
They drink it down... very satisfying.

The second chemist says, "I'll have some H Two O Too"
i.e. H_2O_2
A clear liquid in a glass arrives...
They drink it down....
...and die!

H_2O = water, good to drink!
H_2O_2 = hydrogen peroxide, looks like water, dangerous / deadly to drink

One extra atom affects the reactivity!
Nomenclature very important!

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Nomenclature

Nomenclature: a set of rules used to generate names for chemical compounds - or, being able to "talk the talk" of chemistry

Important to describe H_2O (essential to life) versus H_2O_2 (deadly oxidizing agent) - one atom (more or less) makes a huge difference

This is arguably the most important chapter of CH 151!

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Compounds and Molecules

COMPOUNDS are a combination of 2 or more elements in definite ratios by mass.

The character of each element is lost when forming a compound.

MOLECULES are the smallest unit of a compound that retains the characteristics of the compound.

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Bonding, the way **atoms** are attracted to each other to form **molecules**, determines nearly all of the chemical properties. We shall see later that the number "8" is very important to chemical bonding.

Bonding can be **ionic** or **covalent**.

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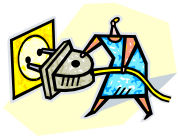
Ions



Atoms are electrically neutral because
number of protons = number of electrons

By gaining or losing electrons an atom can be converted into a charged particle called an ***ion***.

Loss of one or more electrons gives positively charged ion called a ***cation***.

Gaining one or more electrons gives negatively charged ion called a ***anion***.

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IONS AND IONIC COMPOUNDS

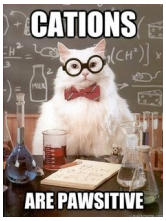
CATIONS have protons > electrons

ANIONS have electrons > protons

Remember:

CATS have PAWS

CATions are PAWSitive



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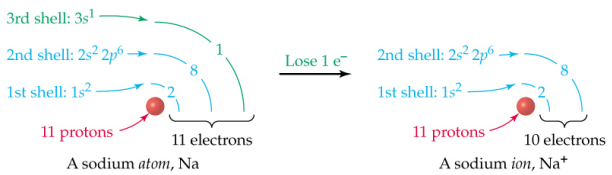
Cations

The symbol for a cation is written by adding a positive charge as a superscript to the symbol for the element.

For example, Na loses an electron to make the sodium cation (Na^+).



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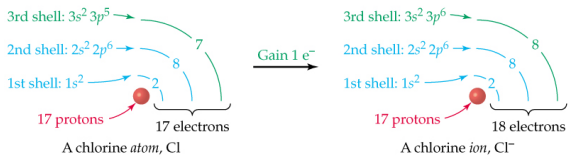
Anions

The symbol for a anion is written by adding a negative charge as a superscript to the symbol for the element.

For example, Cl gains an electron to make the chloride anion (Cl^-).



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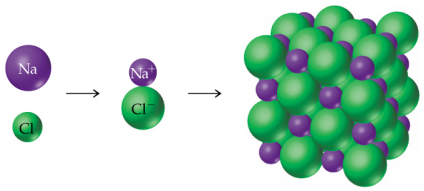
Ionic Bonds

Opposite electrical charges *attract*

When sodium combines with chlorine, sodium transfers electron to chlorine forming Na^+ and Cl^- ions.

The oppositely charged Na^+ and Cl^- ions are held together by a *ionic bond*, making an *ionic compound*.



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Formation of NaCl

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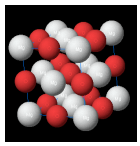
Ionic Compounds

Ionic compounds *usually* form crystalline solids

Ions vary in size and charge.

Ionic compounds have high melting and boiling points.

NaCl, Na^+ and Cl^-, m.p. 804 °C



MgO, Mg^{2+} and O^{2-} m.p. 2800 °C

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Ions of Some Common Elements

Metals of group 1A and 2A form *only* +1 and +2 ions. Ions of these elements all have a noble gas configuration through *electron loss* from their outermost shell.

Group 6A and 7A elements attain noble gas configuration by *gaining* 1 or 2 electrons.

Group 6A: $\cdot\ddot{O}\cdot + 2\,e^- \longrightarrow :\ddot{O}:^{2-}$

$\cdot\ddot{S}\cdot + 2\,e^- \longrightarrow :\ddot{S}:^{2-}$

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"noble gas configuration" means 8 electrons

Ions and the Octet Rule

Octet Rule: Main group elements undergo reactions that leave them with 8 valence electrons or a noble gas configuration - **isoelectronic** (same number of electrons) with noble gases.

All noble gases (except helium) have 8 electrons in their valence shell.

For example, in NaCl, Na^+ and Cl^- have the following electron configurations:

$$\underset{1s^2\,2s^2\,2p^6\,3s^1}{Na} + \underset{1s^2\,2s^2\,2p^6\,3s^2\,3p^5}{Cl} \longrightarrow \underbrace{\underset{1s^2\,2s^2\,2p^6}{Na^+}}_{\text{Neon configuration}} + \underbrace{\underset{1s^2\,2s^2\,2p^6\,3s^2\,3p^6}{Cl^-}}_{\text{Argon configuration}}$$

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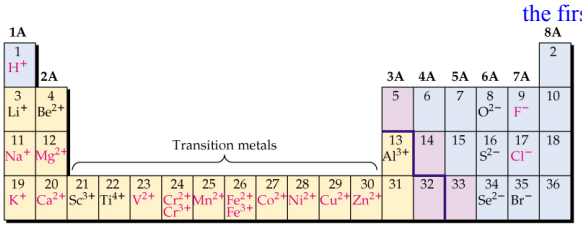
Common ions formed by elements in the first four periods



Groups IA - IIIA: ion usually gets a positive charge equal to the group number

Groups VA - VIIA: ion usually gets a negative charge equal to the group number minus eight

Ex: Aluminum makes the Al^{3+} ion

Ex: Nitrogen makes the N^{3-} ion

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Naming Fixed Charge Cations

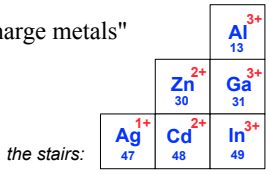
Main group metal cations (Groups 1A, 2A, and "the stairs") named by identifying the metal, followed by the word "ion":

K^+ Potassium ion

Mg^{2+} Magnesium ion

Al^{3+} Aluminum ion

These metals are called "fixed charge metals"



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Naming Anions

Main group nonmetal anions (Groups VA, VIA, and VIIA) named by identifying the nonmetal and *changing ending to "ide"* followed by the word "ion":

Cl^- Chloride ion

O^{2-} Oxide ion

P^{3-} Phosphide ion

C^{4-} Carbide ion

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Naming Variable Charge Cations

Many metals (transition, lanthanide, actinide, etc.) can often form more than one type of cation. Use Roman number to describe charge on metal:

Cr^{2+}	Cr^{3+}
Chromium(II) ion	Chromium(III) ion

Roman numeral indicates charge on cation:

iron(III) would be Fe^{3+}

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A *Polyatomic ion* is an ion composed of more than one atom. Formula for polyatomic ions shown by subscripts. *Example:* SO_4^{2-} ion has one sulfur atom, four oxygen atoms and a -2 charge

Many polyatomic ions known - *memorize*!

CATION: Positive Ion

NH_4^+	ammonium ion

ANIONS: Negative Ions

Based on a Group 4A element		***Based on a Group 7A element***	
CN^-	cyanide ion	ClO^-	hypochlorite ion
$CH_3CO_2^-$	acetate ion	ClO_2^-	chlorite ion
CO_3^{2-}	carbonate ion	ClO_3^-	chlorate ion
HCO_3^-	hydrogen carbonate ion (or bicarbonate ion)	ClO_4^-	perchlorate ion
Based on a Group 5A element		***Based on a transition metal***	
NO_2^-	nitrite ion	CrO_4^{2-}	chromate ion
NO_3^-	nitrate ion	$Cr_2O_7^{2-}$	dichromate ion
PO_4^{3-}	phosphate ion	MnO_4^-	permanganate ion
HPO_4^{2-}	hydrogen phosphate ion		
$H_2PO_4^-$	dihydrogen phosphate ion		
Based on a Group 6A element			
OH^-	hydroxide ion		
SO_3^{2-}	sulfite ion		
SO_4^{2-}	sulfate ion		
HSO_4^-	hydrogen sulfate ion (or bisulfate ion)		

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Polyatomic Ions

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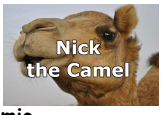
Introducing: Nick the Camel!

Nick *the* Camel Brat *ate* Icky Clam *for* Supper *in* Phoenix

Nick the Camel

Nick *the* Camel Brat *ate* Icky Clam *for* Supper *in* Phoenix



	Consonants = Oxygen	Vowels = Charge	Polyatomic Ion
Nick = Nitrate	3	-1	NO_3^-
Camel = Carbonate	3	-2	CO_3^{2-}
Brat = Bromate	3	-1	BrO_3^-
Icky = Iodate	3	-1	IO_3^-
Clam = Chlorate	3	-1	ClO_3^-
Supper = Sulfate	4	-2	SO_4^{2-}
Phoenix = Phosphate	4	-3	PO_4^{3-}
Did Nick have Crepes for dessert too? :)			
Crepes = chromate	4	-2	CrO_4^{2-}

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Naming Ionic Compounds

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Ionic compounds are named by citing first the cation and then the anion with a space between the words. For example:

$NaBr$ – Sodium bromide

$MgSO_4$ – Magnesium sulfate

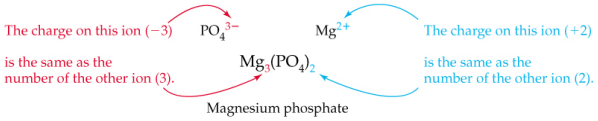
$SnCl_2$ – Tin(II) chloride

$SnCl_4$ – Tin(IV) chloride

Al_2O_3 – Aluminum oxide

Formulas of Ionic Compounds

Formula of an ionic compound shows the *lowest possible ratio* of atoms in the compound.



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Practice, practice, practice!!!

Formulas of Ionic Compounds

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$Na^+ + Cl^- = NaCl$

$Ca^{+2} + Cl^- = CaCl_2$

$Ca^{+2} + O^{-2} = CaO$

$Na^+ + O^{-2} = Na_2O$

$Al^{+3} + S^{-2} = Al_2S_3$

$Ca^{+2} + N^{-3} = Ca_3N_2$

$Li^+ + Br^- =$ $LiBr$

$Mg^{+2} + F^- =$ MgF_2

$Al^{+3} + I^- =$ AlI_3

$NH_4^+ + PO_4^{-3} =$ $(NH_4)_3PO_4$

Not $NH_{43}PO_4$

$Sr^{+2} + P^{-3} =$ Sr_3P_2

$K^+ + Cl^- =$ KCl

Make final compound neutral

Learning Check

Write the formulas and names for compounds of the following ions:

	Br^-	S^{2-}	N^{3-}
Na^+			
Al^{3+}			
Sn^{2+}			
Sn^{4+}			

Remember: To write formulas, cross the charge. To write the name, name the cation (Roman numeral if necessary) then the anion.

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Learning Check - *Answers*

Write the formulas and names for compounds of the following ions:

	Br^-	S^{2-}	N^{3-}
Na^+	NaBr sodium bromide	Na_2S sodium sulfide	Na_3N sodium nitride
Al^{3+}	$AlBr_3$ aluminum bromide	Al_2S_3 aluminum sulfide	AlN aluminum nitride
Sn^{2+}	$SnBr_2$ tin(II) bromide	SnS tin(II) sulfide	Sn_3N_2 tin(II) nitride
Sn^{4+}	$SnBr_4$ tin(IV) bromide	SnS_2 tin(IV) sulfide	Sn_3N_4 tin(IV) nitride

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Learning Check

Write formulas and names for compounds of the following ions.

	OH^-	CO_3^{2-}	PO_4^{3-}
NH_4^+			
Ca^{2+}			

Remember: To write formulas, cross the charges. To name an ionic compound, name the cation (with Roman numeral if necessary), then the anion. If you need more than one polyatomic ion, use parentheses with the number of ions as a subscript.

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Learning Check - Answers

Write formulas and names for compounds of the following ions.

	OH^-	CO_3^{2-}	PO_4^{3-}
NH_4^+	NH_4OH ammonium hydroxide	$(NH_4)_2CO_3$ Ammonium carbonate	$(NH_4)_3PO_4$ ammonium phosphate
Ca^{2+}	$Ca(OH)_2$ Calcium hydroxide	$CaCO_3$ Calcium carbonate	$Ca_3(PO_4)_2$ calcium phosphate

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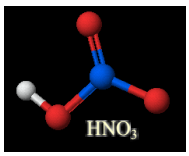
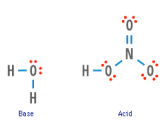
H^+ and Acids

The *Hydrogen cation* (H^+) contains only a proton (no electrons or neutrons).

Acids are substances that provide H^+ ions in water; for example, HCl, H_2SO_4, HNO_3.

HCl dissolved in water → $H^+ + Cl^-$





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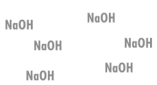
OH^- Ions and Bases

The *Hydroxide anion* (OH^-) is a polyatomic ion with a -1 charge.

Bases are substances that provide OH- ions in water; for example, NaOH, KOH, $Ba(OH)_2$.

NaOH dissolved in water → $Na^+ + OH^-$



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Test Yourself: Ionic Compounds

Give the names for the following formulas:

NaCl
$CaBr_2$
MnF_2
$Ga_2(SO_4)_3$
$Cr(NO_3)_3$

Give the formulas for the following names:

hydrochloric acid
iron(III) oxide
potassium hydroxide
chromium(III) iodide

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Practice, practice, practice!

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Covalent Bonds

A ***covalent bond*** is a bond formed by sharing electrons between atoms.

A ***molecule*** is a group of atoms held together by covalent bonds.

Nonmetals form covalent bonds with nonmetals. They reach the Noble Gas configuration by *sharing* an appropriate number of electrons.

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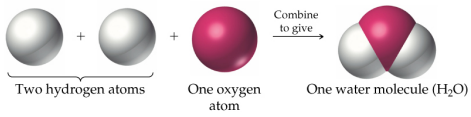
A water molecule results when two hydrogen atoms and one oxygen atom are covalently bonded:



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Test Yourself

Are these compounds bonded through ionic or covalent bonding?

PCl_5
Na_2O
SO_3
$CaSO_3$
SbAs

Nomenclature *of covalent compounds different from ionic compounds; important to know the difference*

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Naming Molecular Compounds

When two or more nonmetal elements combine they form *covalent compounds*.

The formulas of covalent compounds are written with the less electronegative (*i.e. more metal-like*) element first.

More electronegative element gets *-ide* suffix

Use Greek Prefixes to indicate number of atoms present.

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Greek Prefixes

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

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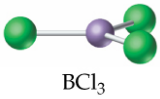
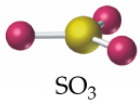
Covalent compounds and nomenclature:



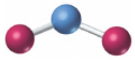
boron trichloride

BCl_3



SO_3

sulfur trioxide



NO_2

nitrogen dioxide

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Test Yourself - Covalent Bonding

Give the names for the following formulas:

N_2O_5
SO_2
OF_2
P_2O_3
NO

Give the formulas for the following names:

tetraphosphorus decaoxide
carbon dioxide
carbon monoxide
nitrogen dioxide

Practice, practice, practice!

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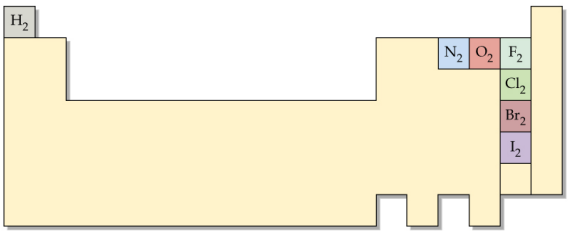
Most elements exist as individual atoms.

Seven elements *always* exist as diatomic molecule - the seven diatomics



HONCl BrIF

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Elements that Exist as Diatomic Molecules

Have
No
Fear
Of
Ice
Clear
Brew

Nitrogen, N_2

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End of Chapter 4 (section 4.3)