Chapter 3
Ionic compounds

3.1 Ions

Atoms have the ability to gain or loose electrons and become **ions**.

Ion: an electrically charged atom or group of atoms.

Cation: an atom that has lost one or more electrons
(a positively charged ion).

– _____ tend to become **cations**.

Anion: an atom that has gained one or more electrons
(a negatively charged ion.)

– _____ tend to become **anions**.

Writing Ions

We write the charge for an ion in the upper right-hand corner of the atomic symbol.
- One (+) for each electron lost
- one (-) for each electron gained.

The number comes **before** the +/- symbol.

Problem: An aluminum atoms loose three electrons when it becomes an ion.
a) Write the symbol for the ion that results.
b) Is it a cation or an anion?

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Problem: An oxygen atoms gains two electrons when it becomes an ion.
a) Write the symbol for the ion that results.
b) Is it a cation or an anion?

(sections 3.2-3.5 will be saved till the end of the chapter)

3.6 Ions of Some Common Elements

E.g. Group 1 (1A) lose 1 e^- to become 1+ ions (Li^+, Na^+, K^+, Rb^+, Cs^+)
Group 2 (2A) lose 2 e^- to become 2+ ions (Be^{2+}, Mg^{2+}, Ca^{2+}, Sr^{2+}, Ba^{2+})
Group 13 (3A) lose 3 e^- to become 3+ ion (Al^{3+})
Group 17 (7A) gain 1 e^- to become 1– ions (F^-, Cl^-, Br^-, I^-)
Group 16 (6A) gain 2 e^- to become 2– ions (O^{2-}, S^{2-}, Se^{2-})
Group 15 (5A) gain 3 e^- to become 3– ions (N^{3-}, P^{3-})

3.7-3.8 Naming Ions

The procedure for naming an ion will depend on if it looses electrons to become a cation or gains electrons to become an anion as well as a few other factors we will investigate.

1. Monatomic anions

Named by replacing the ending of the element's name with "**ide**".

Group 17 anions (of halogens) are called **halides**

Practice: Write the formula and give the name for the anion that forms when the following elements gain enough electrons to fill their octet.

Element	ion symbol	ion name
Cl		
F		
O		
S		
N		

2. Fixed Charge Cations

Groups 1, 2, Al^{3+}, and a few transition elements, which only form 1 valence state or charge, (e.g. **Zn $^{2+}$ Cd^{2+} Sc^{3+} and Ag^+**) form only one ion. They simply have the word "**ion**" added after their name.

Problem: Write the formula and give the name for the cation that can form from the following metals.

- Na
- Mg
- Al

3. Polyatomic Anions

Polyatomic ion: An ion that is composed of more than one atom.

Most polyatomic anions contain oxygen.

The formulas includes subscripts to tell us how many of each type of atom is present in the one polyatomic ion

The atoms in a polyatomic ion are held together by covalent bonds. (a sharing of electrons)

The entire group of atoms act as a single unit.

Ions ending in "**ate**" are most common and indicate the **base number of oxygens** (typically 3 but sulfate and phosphate have 4). Charges vary!

Practice: write names for the following polyatomic ions:

- NO_3^-
- CO_3^{2-}
- ClO_3^-
- SO_4^{2-}
- PO_4^{3-}
- BrO_3^-
- IO_3^-

nick the
camel had a
clam for
supper in
phoenix

Consonants give the number of oxygen;

Vowels give the number of negative charges.

Other polyatomic ions you should know:

Ion Name	Formula	Ion Name	Formula
Thiosulfate	$S_2O_3^{2-}$	Acetate	CH_3COO^- aka $CH_3CO_2^-$ aka $C_2H_3O_2^-$
Permanganate	MnO_4^-	Chromate	CrO_4^{2-}

Hydroxide	OH^-	Hydrogen sulfite	HSO_3^-
Dichromate	$Cr_2O_7^{2-}$	Thiocyanate	SCN^-
Hydrogen Carbonate (Bicarbonate)	HCO_3^-	Hydrogen phosphate	HPO_4^{2-}
Oxalate	$C_2O_4^{2-}$	Dihydrogen phosphate	$H_2PO_4^-$
Cyanide	CN^-	Hydrogen sulfate (Bisulfate)	HSO_4^-

Some polyatomic anions can form a series,

ClO_4^- perchlorate ion "per" means _____ "O" than "ate"

ClO_3^- chlorate ion

ClO_2^- chlorite "ite" means _____ "O" than "ate"

ClO^- hypochlorite "hypo" means _____ "O" than "ate"

4. Variable Charge Cations

- Transition metals (most) can have multiple different charges.
- New **Stock System** uses metal name with the valence shown as a Roman Numeral in parenthesis.
- Old **Greek/Latin System** uses **"ic"** ending for the higher common charge and **"ous"** ending for the lower common charge.

These just need to be memorized!

Practice: give the New and Old System names for the following ions.

	New System (Stock System)	**Old System**
Fe^{2+}		
Fe^{3+}		
Sn^{2+}		
Sn^{4+}		
Hg^{2+}		

Many others that are on a list for you to memorize.

5. **Polyatomic cations** (only 3 common ones)

Hg_2^{2+}	
NH_4^+	ammonium ion
H_3O^+	hydronium ion

3.9-10 Formulas and Naming of Ionic Compounds

Naming Ionic Compounds

Name of cation followed by name of anion
Do not include the work "ion" in the name of the compound
Do not name quantities of each ion.

Formulas of Ionic Compounds

- All compounds are neutral.
- The total positive charge (from the cations) must equal the total negative charge (from the anions).
- Polyatomic ions are treated as a single unit.

Case 1: If the charge of the cation and the anion are the same:

1) Write the cation followed by the anion.
2) Do not show charges of the ions in the final formula
3) Do not use parentheses.

Practice: **Formula** **Name** .

$K^+ + F^- \rightarrow$

$Ca^{2+} + O^{2-} \rightarrow$

$Al^{3+} + N^{3-} \rightarrow$

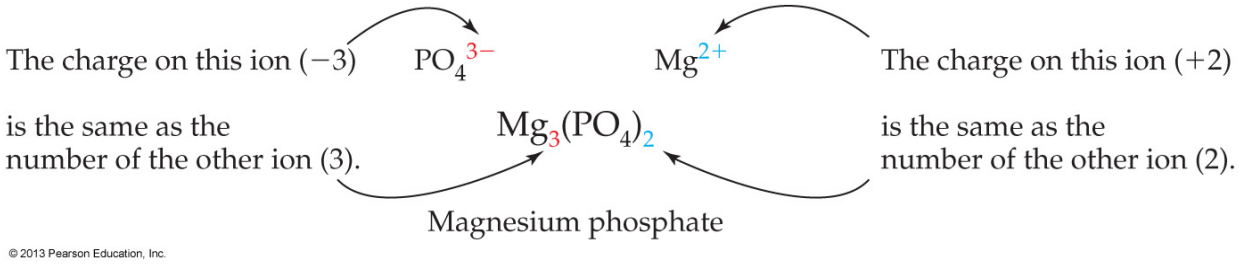
$Sr^{2+} + SO_4^{2-} \rightarrow$

$NH_4^+ + Br^- \rightarrow$

Case 2: If the charges on the anion and cation are different,

1) Use the charge of the cation as a subscript for the anion.
2) Use the charge of the anion as a subscript for the cation.
3) Include polyatomic ions in parentheses if the subscript is >1.
4) Do not show charges of the ions in the final formula.

Note: If both charges are even, divide both numbers by 2.



Practice – using fixed charge cations *(Note: Reactants are not balanced.)*

Ions **Formula** **Name** .

$Li^+ + O^{2-} \rightarrow$

$Mg^{2+} + Cl^- \rightarrow$

$Al^{3+} + S^{2-} \rightarrow$

$Cd^{2+} + NO_3^- \rightarrow$

$NH_4^+ + N^{3-} \rightarrow$

$Sr^{2+} + S^{2-} \rightarrow$

$Pb^{4+} + O^{2-} \rightarrow$

More Practice – using variable charge cations:

Formula	new (Stock) name	old name
Cu_2SO_4		
$Sn(NO_3)_4$		
$PbCO_3$		
Hg_2Br_2		
$FePO_4$		

3.11 H^+ and OH^- Ions: An Introduction to Acids & Bases

Acids and Bases

Two of the most important ions we will study are

the **hydrogen ion:** _____ and

the **hydroxide ion:** _____ ions.

A hydrogen ion is simply a proton.

When acids dissolve in water, the proton can attach to a water molecule to form a hydronium ion.

Chemists use hydrogen and hydronium ions interchangeably in water solutions.

Acid – A substance that provides H+ ions in water.
(e.g. HCl, HNO_3, H_2SO_4, H_3PO_4 are among the most common.)

Base – A substance that provides OH^- ions in water.
(e.g. NaOH, KOH, $Ba(OH)_2$, $Ca(OH)_2$, and NH_4OH are among the most common.)

Naming acids. (in water)

The name of the acid depends on the type of anion present.

Case 1: If the anion contains no oxygen atoms, the acid is named by adding a prefix of hydro to the name of the anion, changing the ending to ic, and adding the word acid.

HCl	**hydrochloric acid**	HF
HBr	**hydrobromic acid**	HCN
HI	**hydroiodic acid**	H_2S

Case 2: If the anion contains oxygen atoms, the acid is named based on the varying number of O atoms.

Show a formation reaction:

There is a series of "base" anions that you must memorize. These anions all end in "ate". The acids made by adding enough H atoms to get a neutral compound are named by changing the "ate" to "ic" and adding the work acid.

Convert the "base" oxyanion that we learned earlier to their corresponding acids.

Practice: write formulas & names for the acids made from the following polyatomic ions:

- NO_3^- nitrate ion . _____
- CO_3^{2-} carbonate ion . _____
- ClO_3^- chlorate ion . _____
- BrO_3^- bromate ion . _____
- SO_4^{2-} sulfate ion . _____
- PO_4^{3-} phosphate ion . _____

Acids can also be made from the series of oxyanions.

For the name, change "ate" to "ic or "ite" to "ous" and add the word acid.

Example

Ion Formula	Ion Name	Acid Formula	Acid Name
ClO_4^-	perchlorate ion	$HClO_4$	perchloric acid
ClO_3^-	chlorate ion	$HClO_3$	chloric acid
ClO_2^-	chlorite	$HClO_2$	chlorous acid
ClO^-	hypochlorite	$HClO$	hypochlorous acid

Now student practice

Ion Formula	Ion Name	Acid Formula	Acid Name
BrO_4^-	perbromate ion		
BrO_3^-	bromate ion		
BrO_2^-	bromite		
BrO^-	hypobromite		
IO_4^-	periodate ion		
IO_3^-	iodate ion		
IO_2^-	iodite		
IO^-	hypoiodite		

Protic Nature of Acids.

Different acids can provide different numbers of H^+ ions per acid molecule.

- Hydrochloric acid, HCl, provides one H^+ ion per acid molecule. **(**_____)
- Sulfuric acid, H_2SO_4, can provide two H^+ ions per acid molecule. **(**_____)
- Phosphoric acid, H_3PO_4, can provide three H^+ ions per acid molecule. **(**_____)

Diprotic and triprotic can be grouped together as **polyprotic** acids.

Bases.

- Sodium hydroxide (NaOH) and potassium hydroxide (KOH) are bases.
- When these compounds dissolve, **OH^-** anions go into solution along with the metal cation.
- Different bases can provide different numbers of OH^- ions per formula unit.
  - Sodium hydroxide (NaOH) provides _____.
    OH^- ion per formula unit.
  - Barium hydroxide, $Ba(OH)_2$ can provides_____.
    OH^- ions per formula unit.