

Cations and Anions



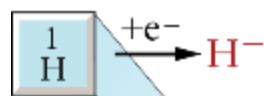
- Atoms of the metallic elements have relatively weak attractions for their electrons, so they tend to lose electrons and form monatomic cations (cations composed of one atom, such as Na^+).
- Atoms of the nonmetallic elements have relatively strong attractions for electrons, so they tend to gain electrons and form monatomic anions (anions composed of one atom, such as Cl^-).
- Therefore, when metallic and nonmetallic atoms combine, they usually form ions and ionic bonds.

Predicting Ion Charges

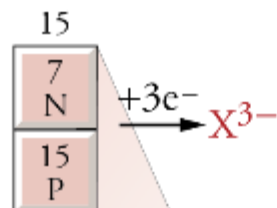
- Noble gas atoms are very stable, so when the nonmetallic atoms form anions, they gain enough electrons to get the same number of electrons as the nearest larger noble gas atom.
- When the aluminum and the metallic atoms in Groups 1, 2, and 3 form cations, they lose enough electrons to get the same number of electrons as the nearest smaller noble gas atom.

The Making of an Anion

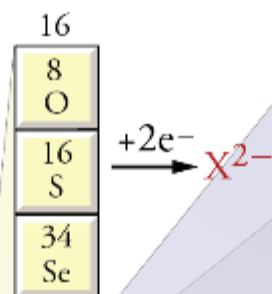
When a hydrogen atom gains one electron,



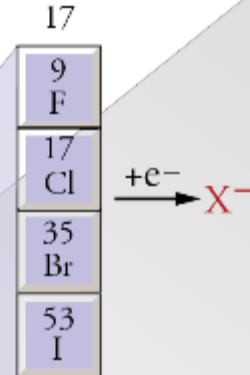
or when an atom in group 15 gains three electrons,



or when an atom in group 16 gains two electrons,



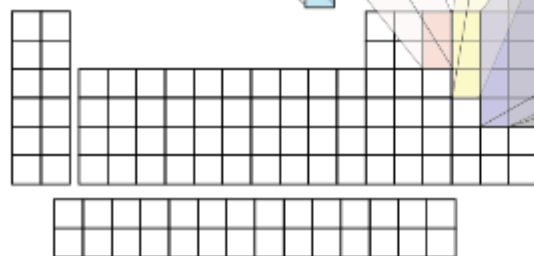
or when an atom in group 17 gains one electron,



it has the same number of electrons as an atom of the nearest noble gas.

18
2 He
10 Ne
18 Ar
36 Kr
54 Xe

Atomic number equals number of electrons.



The Making of a Cation

When an atom in group 1 loses one electron,

1
3 Li
11 Na
19 K
37 Rb
55 Cs
87 Fr

$-e^- \rightarrow X^+$

or when an atom in group 2 loses two electrons,

2
4 Be
12 Mg
20 Ca
38 Sr
56 Ba
89 Ra

$-2e^- \rightarrow X^{2+}$

or when an atom in group 3 loses three electrons,

3
21 Sc
39 Y

$-3e^- \rightarrow X^{3+}$

or when an aluminum atom loses three electrons,

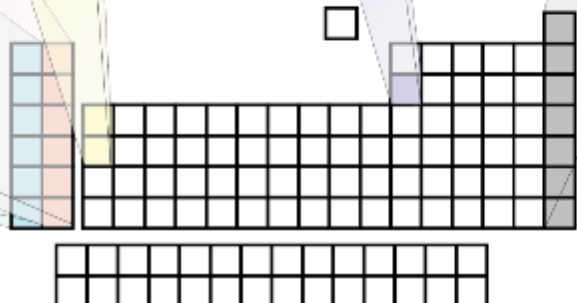
13
13 Al

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

it has the same number of electrons as an atom of the nearest noble gas.

18
2 He
10 Ne
18 Ar
36 Kr
54 Xe
86 Rn

Atomic number equals number of electrons.



Monatomic Ions

1 1A	2 2A											13 3A	14 4A	15 5A	16 6A	17 7A	18 8A
Li ⁺	Be ²⁺													N ³⁻	O ²⁻	F ⁻	
Na ⁺	Mg ²⁺	3 3B	4 4B	5 5B	6 6B	7 7B	8 8B	9 8B	10 8B	11 1B	12 2B	Al ³⁺		P ³⁻	S ²⁻	Cl ⁻	
K ⁺	Ca ²⁺	Sc ³⁺					Fe ²⁺ Fe ³⁺			Cu ⁺ Cu ²⁺	Zn ²⁺				Se ²⁻	Br ⁻	
Rb ⁺	Sr ²⁺	Y ³⁺								Ag ⁺	Cd ²⁺					I ⁻	
Cs ⁺	Ba ²⁺																
Fr ⁺	Ra ²⁺																



Monatomic Ion Names



- Monatomic Cations
 - (name of metal)
 - Groups 1, 2, and 3 metals
 - Al^{3+} , Zn^{2+} , Cd^{2+} , Ag^{+}
 - (name of metal)(Roman numeral)
 - All metallic cations not mentioned above
- Monatomic Anions
 - (root of nonmetal name)ide

Monatomic Anions

hydride, H^-

nitride, N^{3-}

phosphide, P^{3-}

oxide, O^{2-}

sulfide, S^{2-}

selenide, Se^{2-}

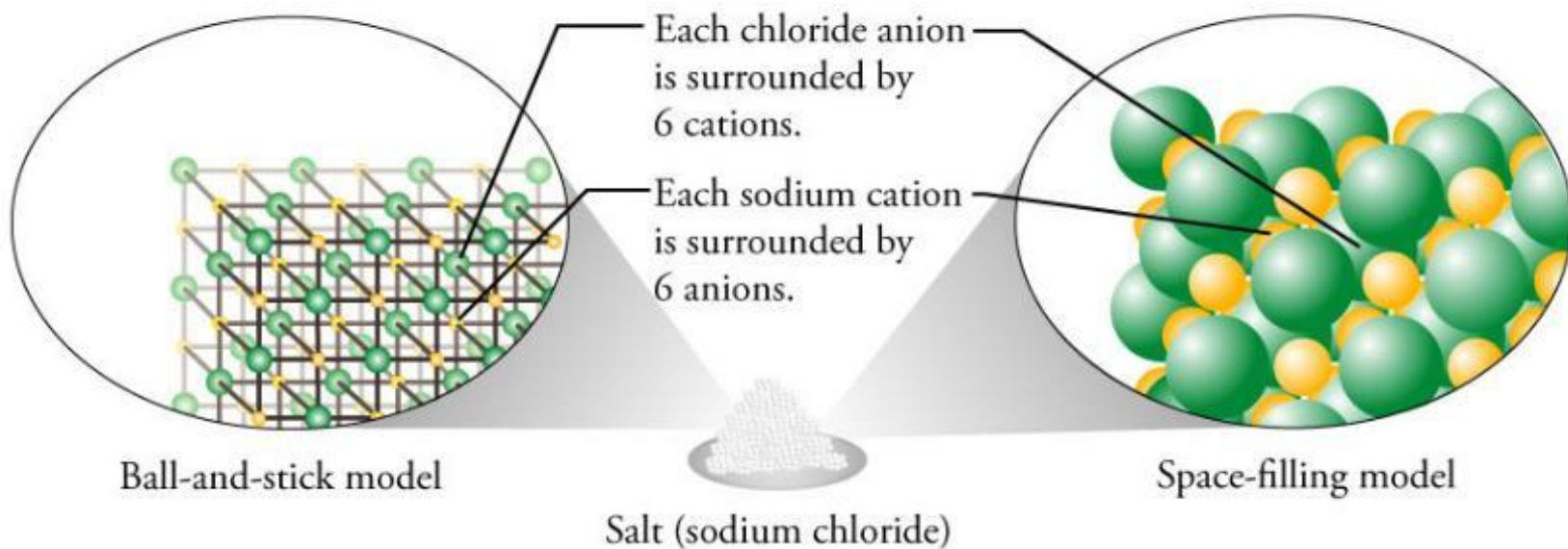
fluoride, F^-

chloride, Cl^-

bromide, Br^-

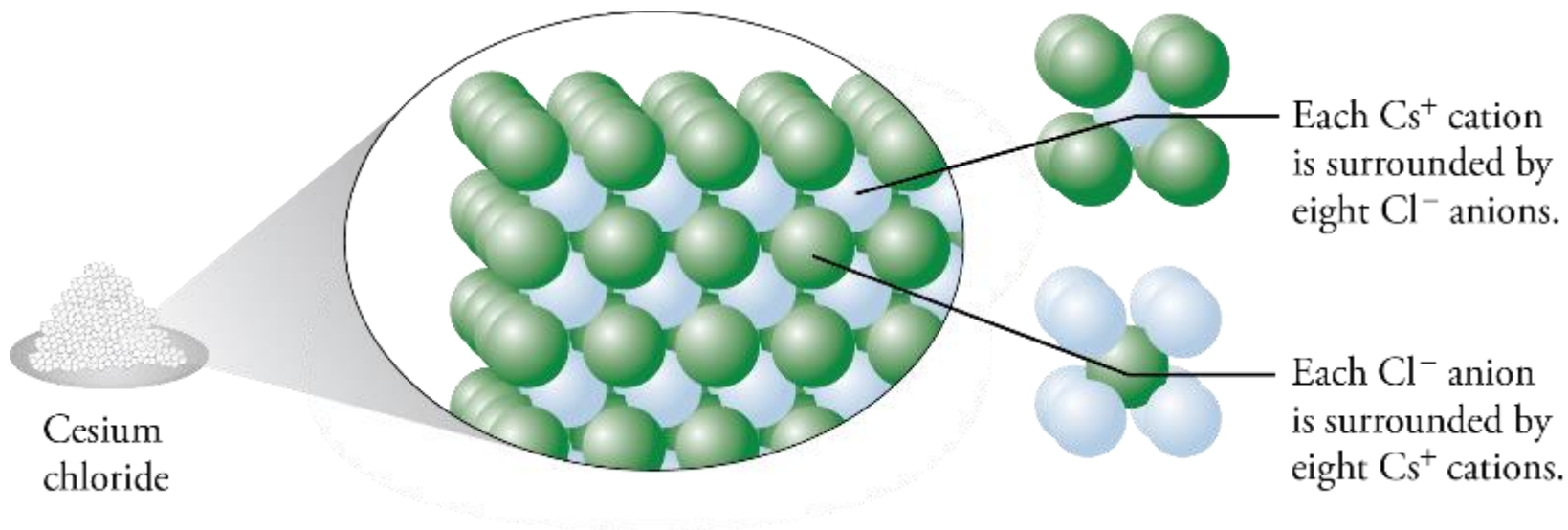
iodide, I^-

Sodium Chloride, NaCl, Structure



Cesium chloride, CsCl, Structure

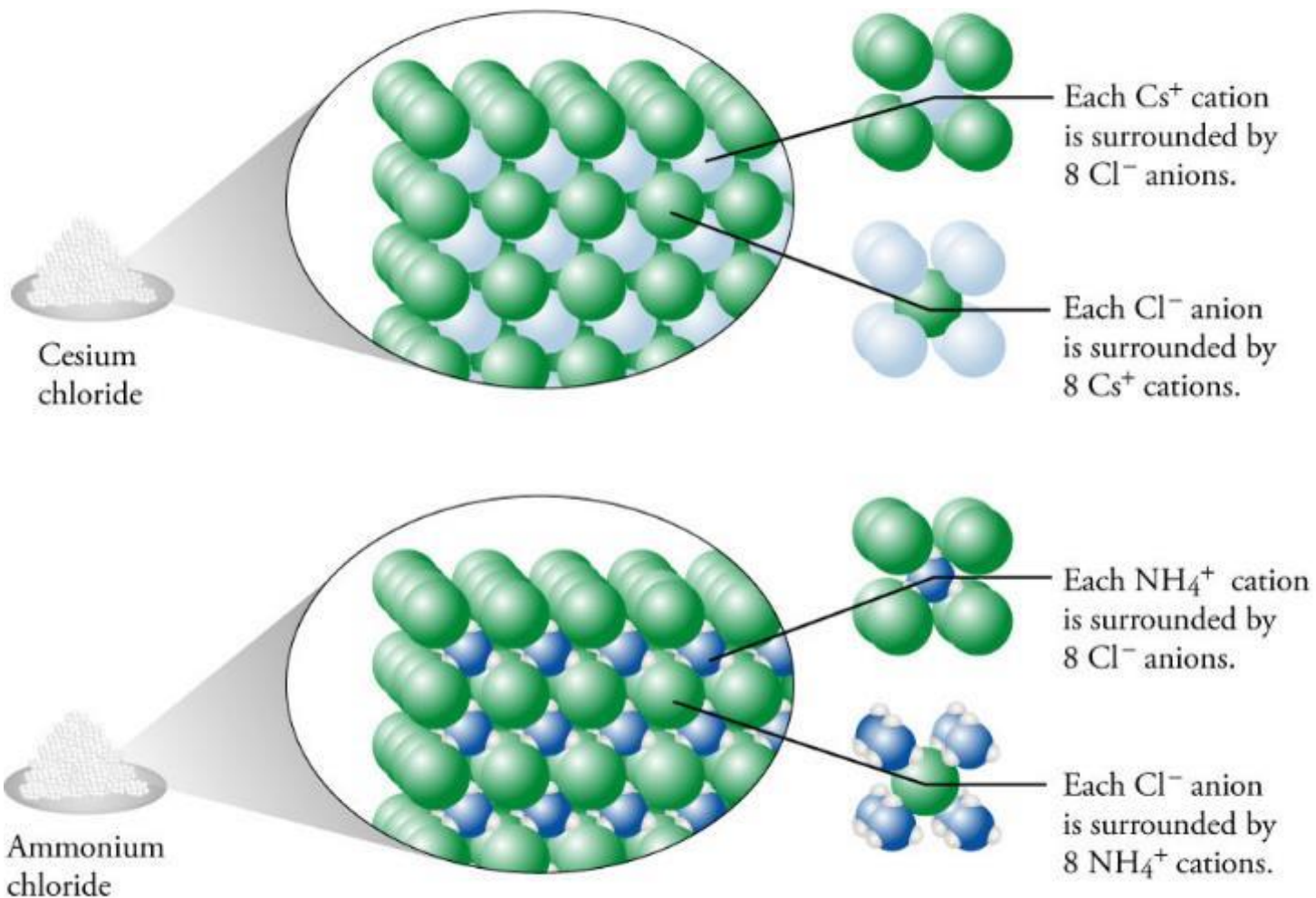
- Because the cesium ions are larger than sodium ions, there is room for eight chloride ions around each cesium ion and eight cesium ions around each chloride ion.



Polyatomic Ions

- Some anions and cations contain more than one atom.
- **Polyatomic ion** = a charge collection of atoms held together by covalent bonds
- For example, it is possible for a nitrogen atom to form covalent bonds to four hydrogen atoms, but to make this possible the nitrogen atom has to lose an electron, giving the collection of atoms a plus one charge. This will be explained in more detail in a later lesson. This collection of atoms with the formula NH_4^+ is called the ammonium ion.

CsCl and NH₄Cl structure




Polyatomic Ions

Ion	Name	Ion	Name
NH_4^+	ammonium	NO_3^-	nitrate
OH^-	hydroxide	SO_4^{2-}	sulfate
CO_3^{2-}	carbonate	$\text{C}_2\text{H}_3\text{O}_2^-$	acetate
PO_4^{3-}	phosphate		

Polyatomic Ions with Hydrogen

- HCO_3^- hydrogen carbonate (bicarbonate)
- HSO_4^- hydrogen sulfate
- HS^- hydrogen sulfide
- HPO_4^{2-} hydrogen phosphate
- H_2PO_4^- dihydrogen phosphate

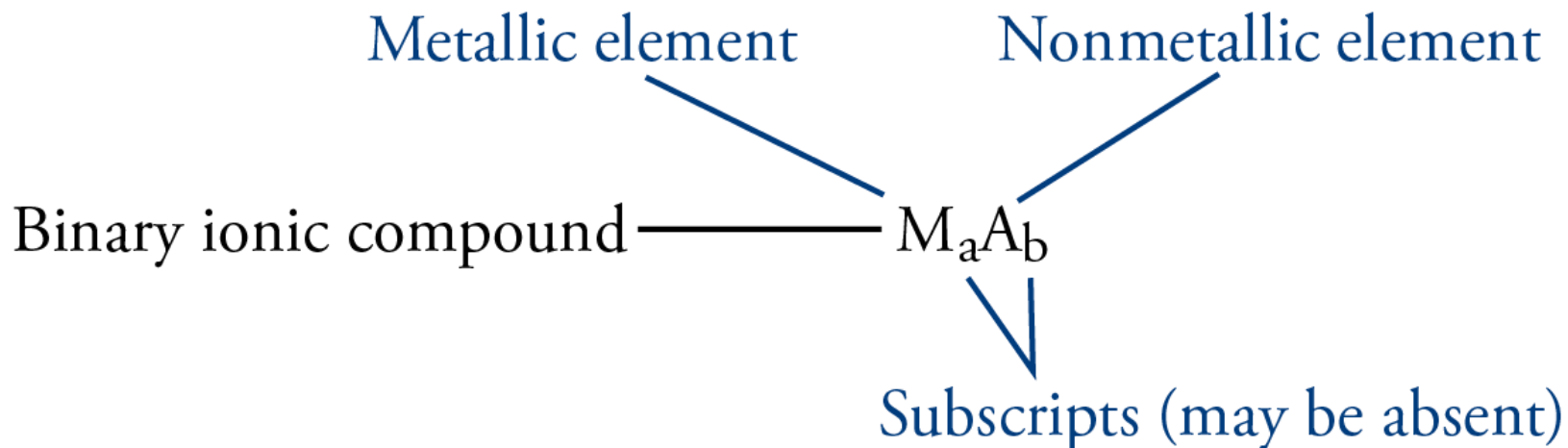
Recognizing Ionic Formulas and Names



- Different types of compounds have different guidelines for writing their names or formulas.
- Therefore, the first step in converting between names and formulas for chemical compounds is classifying them with respect to type.
- The simplest way to identify a formula as representing an ionic compound is to see a symbol for a metal or NH_4 at the beginning of the formula.
- The simplest way to identify a name as representing an ionic compound is to see the name of a metal or ammonium at the beginning of the name.

Recognizing Binary Ionic Compounds

- Binary means two, and in the case of binary ionic compounds, the word binary means two elements, a metallic element and a nonmetallic element.
- If a formula has a symbol for a metal and a symbol for a nonmetal, it's a binary ionic compound composed of a monatomic cation and a monatomic anion.



Converting Ionic Names to Formulas

- Ionic compound names include the name of the cation followed by the name of the anion.
- The following table summarizes cation names.

Metals with one possible charge (Al, Zn, Cd, (Ag), and Groups 1, 2, 3)	name of metal
Metals with more than one possible charge (the rest)	name(Roman numeral)
polyatomic cations (e.g. ammonium)	name of polyatomic ion

Anion Names

- The following table summarizes anion names.

monatomic anion	(root of nonmetal name)ide
polyatomic anion	name of polyatomic ion

Converting Ionic Formulas to Names



- What's the name of MgO?
 - Magnesium is in Group 2, so it is always +2.
 - The name for Mg^{2+} is magnesium.
 - The anion is O^{2-} , which is a monatomic anion.
 - Monatomic anions are named by combining the root of the name of the nonmetal and -ide.
 - The anion name is oxide.
 - The names of ionic compounds combine the name of the cation and the name of the anion.
 - MgO is magnesium oxide.

Converting Ionic Formulas to Names




- What's the name of CoCl_2 ?
 - Co represents cobalt, and cobalt is not on the list of elements that have only one charge, so we need a Roman numeral indicating its charge in the cobalt ion name.
 - We can determine the cobalt ion charge from recognizing that the chloride is -1, two of them would be -2, so the cobalt ion must be +2.
 - The name for Co^{2+} is cobalt(II).
 - The anion is Cl^- , so its name is chloride.
 - The name of CoCl_2 is cobalt(II) chloride.

Converting Ionic Formulas to Names




- What's the name of NH_4NO_3 ?
 - Although this formula contains symbols for all nonmetallic elements, we recognize that this formula represents an ionic compound because we see NH_4 in the formula.
 - You need to memorize formulas and names of polyatomic ions.
 - NH_4^+ is named ammonium.
 - NO_3^- is nitrate.
 - The name of NH_4NO_3 is ammonium nitrate.

Identifying Names as Ionic Compounds



- The following general names tell you that the name represents an ionic compound.
 - (name of metal) (root of nonmetal)ide
 - e.g. calcium oxide
 - (name of metal)(Roman #) (root of nonmetal)ide
 - e.g. iron(II) oxide
 - ammonium (root of nonmetal)ide
 - e.g. ammonium oxide
 - ammonium (name of polyatomic anion)
 - e.g. ammonium sulfate

Writing Ionic Formulas



- Two steps for writing formulas for ionic compounds.
 - Determine the formula, including charge, for the cation and anion.
 - Determine the ratio of the ions that yields zero overall charge.

Formulas and Charges of Ions



- We can predict the formulas including charge for some of the ions by
 - memorizing names and symbols for some of the elements,
 - using the periodic table to predict the charges for some elements,
 - and memorizing formulas and charges for other ions.
- You can find a web-based tool that will allow you to practice converting between names and symbols at

https://preparatorychemistry.com/element_names_symbols_Canvas.html

Monatomic Ions

1 1A	2 2A											13 3A	14 4A	15 5A	16 6A	17 7A	18 8A
Li ⁺	Be ²⁺													N ³⁻	O ²⁻	F ⁻	
Na ⁺	Mg ²⁺	3 3B	4 4B	5 5B	6 6B	7 7B	8 8B	9 8B	10 8B	11 1B	12 2B	Al ³⁺		P ³⁻	S ²⁻	Cl ⁻	
K ⁺	Ca ²⁺	Sc ³⁺					Fe ²⁺ Fe ³⁺			Cu ⁺ Cu ²⁺	Zn ²⁺				Se ²⁻	Br ⁻	
Rb ⁺	Sr ²⁺	Y ³⁺								Ag ⁺	Cd ²⁺					I ⁻	
Cs ⁺	Ba ²⁺																
Fr ⁺	Ra ²⁺																



Polyatomic Ions

Ion	Name	Ion	Name
NH_4^+	ammonium	NO_3^-	nitrate
OH^-	hydroxide	SO_4^{2-}	sulfate
CO_3^{2-}	carbonate	$\text{C}_2\text{H}_3\text{O}_2^-$	acetate
PO_4^{3-}	phosphate		

Polyatomic Ions with Hydrogen

- HCO_3^- hydrogen carbonate
- HSO_4^- hydrogen sulfate
- HS^- hydrogen sulfide
- HPO_4^{2-} hydrogen phosphate
- H_2PO_4^- dihydrogen phosphate

Ionic Formulas

Ionic charges	General formula	Example ions	Example formula
X^+ and Y^-	XY	Na^+ and Cl^-	$NaCl$
X^+ and Y^{2-}	X_2Y	NH_4^+ and SO_4^{2-}	$(NH_4)_2SO_4$
X^+ and Y^{3-}	X_3Y	Li^+ and PO_4^{3-}	Li_3PO_4
X^{2+} and Y^-	XY_2	Mg^{2+} and NO_3^-	$Mg(NO_3)_2$
X^{2+} and Y^{2-}	XY	Ca^{2+} and CO_3^{2-}	$CaCO_3$
X^{2+} and Y^{3-}	X_3Y_2	Ba^{2+} and N^{3-}	Ba_3N_2
X^{3+} and Y^-	XY_3	Al^{3+} and F^-	AlF_3
X^{3+} and Y^{2-}	X_2Y_3	Sc^{3+} and S^{2-}	Sc_2S_3
X^{3+} and Y^{3-}	XY	Fe^{3+} and PO_4^{3-}	$FePO_4$

Converting Ionic Names to Formulas



- What's the formula for aluminum chloride?
 - This name has the following form, so it is ionic.
(name of metal) (root of nonmetal)ide
 - The symbol for aluminum is Al. Aluminum atoms have 3 more electrons than neon, so we expect it to lose 3 electron and form Al^{3+} ions.
 - The symbol for chlorine is Cl, which is found in group 17, so chloride is Cl^- .
 - The formula for aluminum chloride is **AlCl_3** .

Converting Ionic Formulas to Names

- What's the formula for chromium(III) oxide?
 - This name has the following form, so it is ionic.
(name of metal)(Roman #) (root of nonmetal)ide
 - The symbol for chromium is Cr. The (III) in the name tells us that the cation formula, including charge, is Cr^{3+} .
 - The symbol for oxygen is O, which is found in group 16, so oxide is O^{2-} .
 - The formula for chromium(III) oxide is **Cr_2O_3** .



Converting Ionic Formulas to Names

- What's the formula for calcium nitrate?
 - There are two ways to recognize this name as representing an ionic compound.
 - The –ate on the end of the name tells us that the compound contains a polyatomic ion.
 - The symbol for the element calcium is Ca, which is a metallic element, and metals in the combined form yield ionic compounds.
 - The symbol Ca is in group 2 on the periodic table, so the charge on calcium ions is +2 – Ca^{2+} .
 - The formula for nitrate is NO_3^- .
 - The formula for calcium nitrate is **$\text{Ca}(\text{NO}_3)_2$** .

Converting Ionic Formulas to Names

- What's the formula for ammonium sulfide?
 - This name has the following form, so it is ionic.
Ammonium (root of nonmetal)ide
 - The formula for ammonium is NH_4^+ .
 - The -ide on the end of the name sulfide, tells us that it is a monatomic anion.
 - The symbol for sulfur is S, which is found in group 16, so sulfide is S^{2-} .
 - The formula for ammonium sulfide is **$(\text{NH}_4)_2\text{S}$** .
 - Note that the formula for the polyatomic ion is in parentheses.

Converting Ionic Formulas to Names



- There are three tools on the textbook's website that will allow you to practice this task.
 - Conversion between cation names and formulas.
https://preparatorychemistry.com/cation_names_formulas_Canvas.html
 - Conversion between anion names and formulas.
https://preparatorychemistry.com/anion_names_formulas_Canvas.html
 - Conversion between ionic compound names and formulas.
https://preparatorychemistry.com/ionic_nomenclature_Canvas.html