

How do I recognize that a compound is ionic, and how do I name it?

The Model: Compounds Containing Polyatomic Ions

In addition to monatomic ions, there are polyatomic ions. Within a **polyatomic ion**, each atom is connected to one or more atoms of the same polyatomic ion. Such connected atoms are **covalently bound** to each other. Atoms connected by a covalent bond share electrons with each other (as opposed to neighboring cations and anions, in which electrons had been transferred from the former to the latter species).

Table 1. Common polyatomic ions. See [page 7](#) for a table of the ions that you need to know in this class.

Cations:	NH ₄ ⁺ H ₃ O ⁺	Ammonium Hydronium	Hg ₂ ²⁺	Mercury (I)
Anions:	C ₂ H ₃ O ₂ ⁻ NH ₂ ⁻ N ₃ ⁻ HCO ₃ ⁻ BO ₃ ³⁻ CO ₃ ²⁻ C ₂ ²⁻ ClO ₃ ⁻ CrO ₄ ²⁻ OCN ⁻ CN ⁻ Cr ₂ O ₇ ²⁻	Acetate Amide Azide Hydrogen carbonate (or bicarbonate) Borate Carbonate Carbide Chlorate Chromate Cyanate Cyanide Dichromate	OH ⁻ ClO ⁻ NO ₃ ⁻ C ₂ O ₄ ²⁻ O ₂ ²⁻ MnO ₄ ⁻ ClO ₄ ⁻ PO ₄ ³⁻ SiO ₄ ⁴⁻ SO ₄ ²⁻ O ₂ ⁻ S ₂ O ₃ ²⁻ I ₃ ⁻	Hydroxide Hypochlorite Nitrate Oxalate Peroxide Permanganate Perchlorate Phosphate Silicate Sulfate Superoxide Thiosulfate Triiodide

Compounds composed of polyatomic ions form crystals with structures similar to that for compounds of monatomic ions – cations and anions stack on top of each other in a periodic array. Suppose we

looked into a crystal of Hg₂I₂ ["mercury (I) iodide"]. We would find planes containing the clusters of ions as shown on the right.

The rectangle includes two formula units and two halves of formula units.

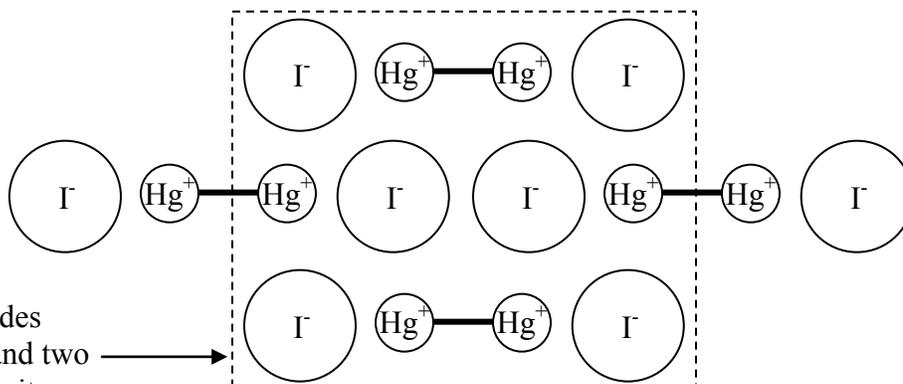


Figure 1. A section of a crystal of mercury (I) iodide, Hg₂I₂

Key Questions

1. What kinds of bonding exist in mercury (I) iodide?
2. Why is the formula for mercury (I) iodide "Hg₂I₂" and not simply "HgI"?

The Model: Nomenclature of Ionic Compounds

Formula	Unambiguous Name	Formula	Unambiguous Name
LiF	lithium fluoride	Mn ₃ (PO ₄) ₂	manganese(II) phosphate
Na ₂ O	sodium oxide	MnPO ₄	manganese(III) phosphate
ZnS	zinc sulfide	Cu(IO ₃) ₂	copper(II) iodate
Al(NO ₃) ₃	aluminum nitrate	SnI ₂	tin(II) iodide
NH ₄ NO ₂	ammonium nitrite	Hg ₃ N ₂	mercury(II) nitride
MgSO ₃	magnesium sulfite	Hg ₂ SO ₄	mercury(I) sulfate
K ₃ AsO ₄	potassium arsenate	PbSeO ₄	lead(II) selenate

Key Questions

3. The name of an ionic compound typically consists of two words separated by a space. Is the first word in the name of an ionic compound that of the cation or that of the anion?

Is the second word that of the cation or that of the anion?

4. Look at the examples in the Model, paying attention to the differences between compounds with anions having similar names (*e.g.*, **nitride** versus **nitrate** versus **nitrite**; **sulfide** versus **sulfate** versus **sulfite**; **iodide** versus **iodate**).
 - a. What is the difference between an anion whose name ends in **-ide** and an anion whose name ends in **-ate** (or **-ite** for that matter)? (*i.e.*, What does an **-ate** anion have that an **-ide** anion does not?)
 - b. What is the charge (both magnitude and sign) of the **nitrate anion**? Based on the formula of **ammonium nitrite**, what is the charge of the nitrite anion?

- 4c. What is the charge (both magnitude and sign) of the *sulfate anion*? Based on the formula of *magnesium sulfite*, what is the charge of the *sulfite anion*?
- d. In general, if you've memorized the formulas of polyatomic anions with names ending in *-ate*, you need not memorize the formulas of the corresponding polyatomic anions ending in *-ite*. In going from *-ate* to *-ite* (e.g., from nitrate to nitrite, or from sulfate to sulfite), what happens to the formula (both in terms of the number of each type of atom in the ion and the overall charge)?
- e. There is a polyatomic ion called "phosphite". Given that the formula of the phosphate ion is PO_4^{3-} , what is the formula (including the charge) of the phosphite ion?
5. Phosphorous and arsenic are in the same column on the Periodic Table. Elements in the same "family" or "Group" will very often have similar chemical reactivities. Since there is a polyatomic ion known as "phosphate", it should not be surprising that there is also an "arsenate". What is the formula for the polyatomic anion called "tellurite"? *Hint*: tellurium, Te, is in the same group on the periodic table, group VIA, as sulfur.
6. LiF is not "lithium (I) fluoride" and it would be ambiguous to refer to $\text{Mn}_3(\text{PO}_4)_2$ as "manganese phosphate".
- a. What does the Roman numeral in parentheses after the name of a metal tell the reader?
- b. When should the Roman numeral in parentheses after the name of a metal be written?
- 7a. What identifies the compound $\text{Sb}_2(\text{SO}_4)_3$ as an ionic compound?
- b. Keeping in mind that antimony cations could have more than one possible charge, what is the unambiguous name of $\text{Sb}_2(\text{SO}_4)_3$?

How do I recognize that compound is an acid, and how do I name it?

The Model: Nomenclature of Acids

Formula	Unambiguous Name	Formula	Unambiguous Name
HCl	hydrochloric acid	H ₂ SO ₄	sulfuric acid
H ₂ S	hydrosulfuric acid	H ₂ SO ₃	sulfurous acid
HCN	hydrocyanic acid	HClO ₄	perchloric acid
		HClO ₃	chloric acid
		HClO ₂	chlorous acid
		HClO	hypochlorous acid

Key Questions

8a. What are the names of the anions in *hydrochloric acid*, *hydrosulfuric acid*, and *hydrocyanic acid*?

Name of anion found in acid

Hydrochloric acid _____

Hydrosulfuric acid _____

Hydrocyanic acid _____

b. What common suffix do these anions share?

9a. What are the names of the anions in *sulfuric acid* and *chloric acid*?

Sulfuric acid _____ Chloric Acid _____

b. What common suffix do these anions share?

10a. What are the names of the anions in *sulfurous acid* and *chlorous acid*?

Sulfurous acid _____ Chlorous Acid _____

b. What common suffix do these anions share?

11. Refer back to Key Questions 8, 9, and 10. In your own words, summarize the rules for...
(a.) when the *hydro-* prefix and *-ic* suffix is used when naming an acid.

(b.) when *only* the *-ic* suffix is used in naming an acid.

(c.) When *only* the *-ous* suffix is used in naming an acid.

12a. What is the name of the polyatomic anion in each of the following acids? (Keep in mind your answer to Key Question 11.)

Name of Polyatomic Ion in Acid

i. *Perchloric acid* _____

ii. *Hypochlorous acid* _____

b. Elements in the same "family" (*i.e.*, group or column of the Periodic Table) will very often have similar chemical reactivities. Since there is an acid known as "chloric acid", it should not be surprising that there is also be a "bromic acid". Write the formulas for the following acids.

i. bromic acid _____

iii. perbromic acid _____

ii. bromous acid _____

iv. hypobromous acid _____

Exercises

Provide the correct, unambiguous name for each of the following. Acids are indicated if followed by (aq), meaning in aqueous solution—*i.e.* dissolved in water.

13. HgS

18. H₂SO₄ (aq)

14. Al₂(CO₃)₃

19 HCl (g)

15. H₃PO₄ (aq)

20. HClO (aq)

16. BaO

21. Ca(HCO₃)₂

17. K₂Cr₂O₇

22. Pb(NO₃)₂

Provide the correct formula for each of the following:

23. Mercury (I) nitrite
24. Iron (III) nitride
25. Strontium sulfite
26. Manganese (II) phosphite
27. Sodium dihydrogen phosphate
28. Phosphorous acid
29. Copper (I) hydrogen phosphate
30. Hydrofluoric acid

List of Elemental Symbols

It is expected that you know the symbols and names (spelling too!) for the following elements from your study in a previous chemistry class. Please note that you will be tested on these symbols.

Element	Symbol
Aluminum	Al
Antimony	Sb
Argon	Ar
Arsenic	As
Barium	Ba
Beryllium	Be
Bismuth	Bi
Boron	B
Bromine	Br
Cadmium	Cd
Calcium	Ca
Carbon	C
Chlorine	Cl
Chromium	Cr
Cobalt	Co
Copper	Cu
Fluorine	F
Gold	Au
Helium	He
Hydrogen	H
Iodine	I
Iron	Fe
Krypton	Kr
Lead	Pb
Lithium	Li
Magnesium	Mg
Manganese	Mn
Mercury	Hg

Element	Symbol
Molybdenum	Mo
Neon	Ne
Nickel	Ni
Nitrogen	N
Oxygen	O
Phosphorus	P
Platinum	Pt
Plutonium	Pu
Potassium	K
Radium	Ra
Radon	Rn
Selenium	Se
Silicon	Si
Silver	Ag
Sodium	Na
Strontium	Sr
Sulfur	S
Tin	Sn
Titanium	Ti
Tungsten	W
Uranium	U
Vanadium	V
Xenon	Xe
Zinc	Zn

List of Common Ions and their Charges

It is expected that you know the names (spelling too!), formulas and charges for the following ions. Please note that you will be tested on these ions.

Positive Ions (Cations)		Negative Ions (Anions)	
1+		1-	
Group IA Elements	Li ⁺ , Na ⁺ , K ⁺ , Rb ⁺ , Cs ⁺	Group VIIA Elements	F ⁻ , Cl ⁻ , Br ⁻ , I ⁻
Ammonium	NH ₄ ⁺	Acetate	C ₂ H ₃ O ₂ ¹⁻ or CH ₃ COO ¹⁻
Hydrogen Hydronium	H ⁺ H ₃ O ⁺	Hydroxide	OH ¹⁻
Silver	Ag ⁺	Perchlorate Chlorate Chlorite Hypochlorite	ClO ₄ ¹⁻ ClO ₃ ¹⁻ ClO ₂ ¹⁻ ClO ¹⁻
Copper (I)	Cu ⁺	Cyanide	CN ¹⁻
Mercury (I)	Hg ₂ ²⁺ (Note that two Hg ¹⁺ ions pair together!)	Hydrogen carbonate (or Bicarbonate) Hydrogen sulfate (or Bisulfate) Dihydrogen phosphate	HCO ₃ ¹⁻ HSO ₄ ¹⁻ H ₂ PO ₄ ¹⁻
Hydronium	H ₃ O ⁺	Nitrate Nitrite	NO ₃ ¹⁻ NO ₂ ¹⁻
2+		2-	
Group IIA Elements	Mg ²⁺ , Ca ²⁺ , Ba ²⁺	Group VIA Elements	O ²⁻ , S ²⁻
Copper (II)	Cu ²⁺	Carbonate	CO ₃ ²⁻
Iron (II)	Fe ²⁺	Sulfate	SO ₄ ²⁻
Lead (II)	Pb ²⁺	Sulfite	SO ₃ ²⁻
Mercury (II)	Hg ²⁺	Hydrogen phosphate	HPO ₄ ²⁻
Zinc	Zn ²⁺	Peroxide	O ₂ ²⁻
3+		3-	
Aluminum	Al ³⁺	Phosphate	PO ₄ ³⁻
Iron (III)	Fe ³⁺		

The following pages summarize the rules for writing the formulas of ionic compounds, naming ionic compounds, naming acids and writing the formula of an acid

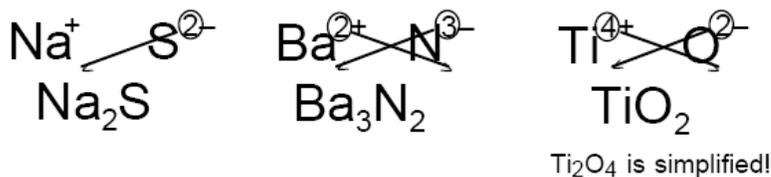
Writing formulas of Ionic Compounds when given the Individual Ions

Rule to obey: compounds must be neutral → total positive charge = total negative charge

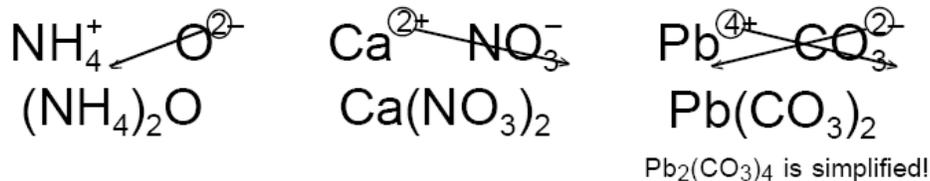
1. If the two ions have exactly opposite charges (+1 and -1, +2 and -2, +3 and -3)
⇒ **formula of the compound contains one of each ion**



- 2a. If two monatomic ions have different charges
⇒ **use crossover rule to get formula of the compound**
- superscript for cation becomes subscript for anion
 - superscript for anion becomes subscript for cation
 - **simplify subscripts** to get lowest ratio of atoms
- (Note: **Only the numbers cross down**, not the signs!)



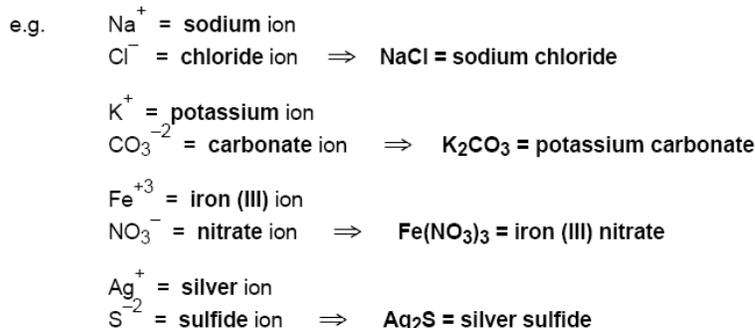
- b. If two ions have different charges and at least polyatomic ion is involved
⇒ **use crossover rule to get formula of the compound**
- if more than one of polyatomic ion in formula, use parentheses
 - **simplify subscripts** to get lowest ratio of atoms
- (Note: Again **only the numbers cross down**, not the signs!)



Naming Ionic Compounds

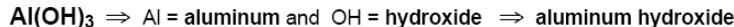
Rule to obey: Ionic compounds are named from the ions they are made of.

Name the cation and the anion, then remove "ion" from each name:

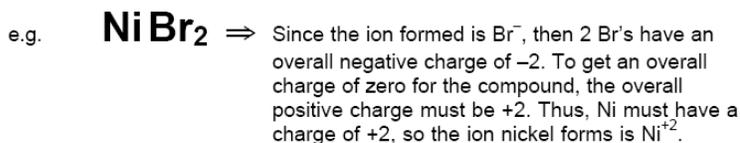


Given the Chemical Formula, Name the Compounds

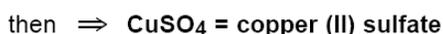
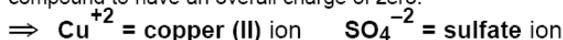
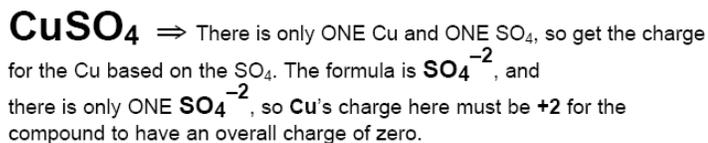
1. If the metal is in Groups IA–IIIA, silver, cadmium, or zinc, then just name the metal cation and the anion:



2. If the metal can form more than one ion,
a. Determine the charge on the cation using the charge on the anion.
b. Name the cation and the anion, then remove "ion" from both



- c. If a polyatomic ion is involved, remember that more than one polyatomic is shown in parentheses—i.e. **DO NOT** multiply the charge of the polyatomic ion with the subscript of the *atoms* in a polyatomic ion.



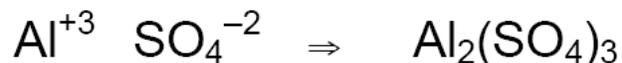
Writing the compound's formula when given its name

Get the individual ions from the name, then combine them using the crossover rule:

e.g. barium chloride \Rightarrow barium = Ba^{+2} chloride = Cl^{-}



aluminum sulfate \Rightarrow aluminum = Al^{+3} sulfate = SO_4^{-2}



Determining Formulas and Names of Acids from the Anion in the Acid

Given an ion,

we can get formula of acid by: adding H atoms equal to negative charge on ion

we can name for acid: depending on suffix of ion name

