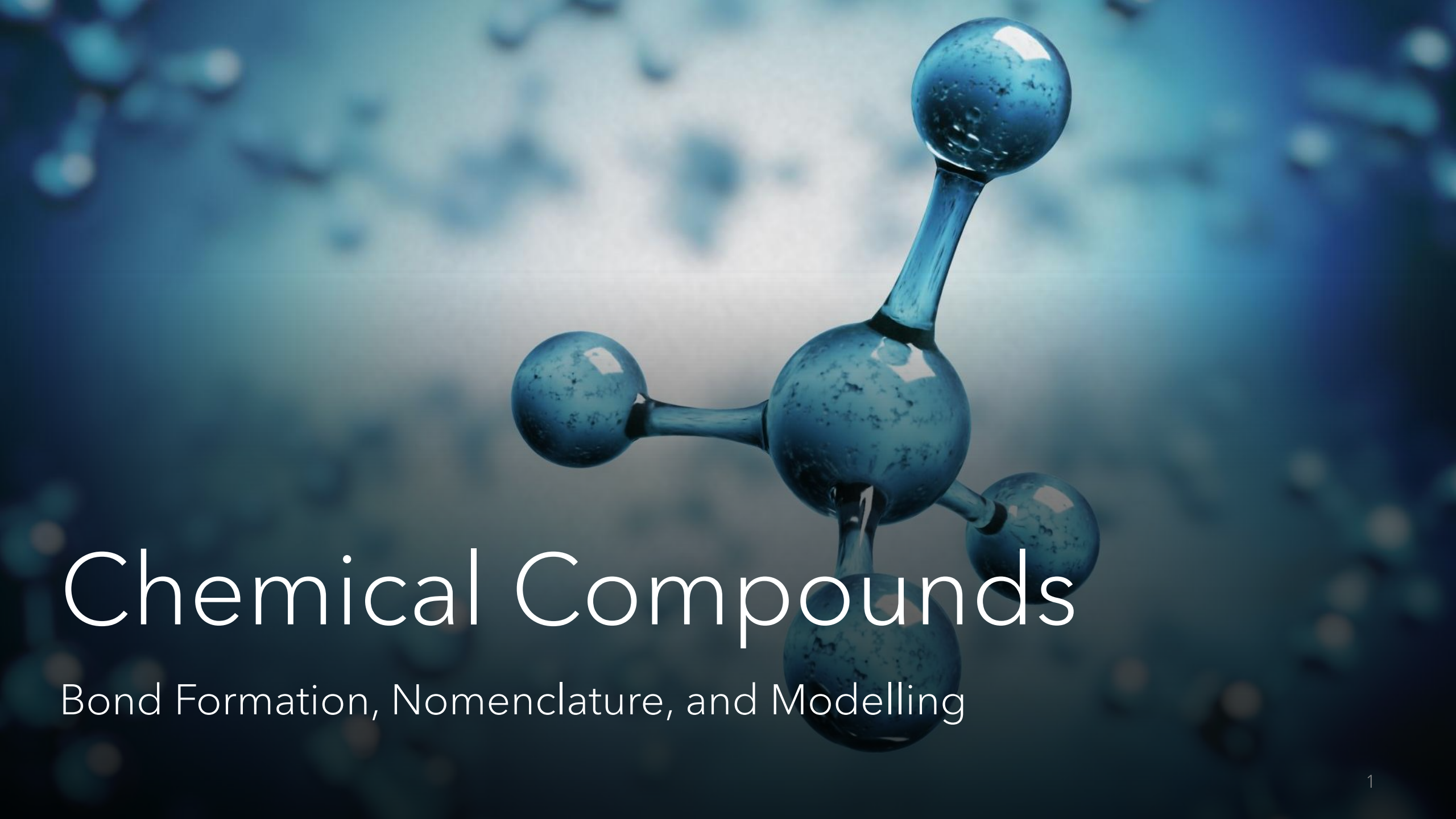


Chemical Compounds

Bond Formation, Nomenclature, and Modelling

Overview

Review: atoms and subatomic particles, ions

Modelling Atoms and Compounds

- Counting Atoms
- Bohr Models
- Lewis Diagrams

IUPAC Naming and Writing Formulas

Balanced Chemical Equations

Section 3: IUPAC Nomenclature

(not covered in textbook)

Chemical Nomenclature (Naming)

It is important to have *one* system to name chemical compounds. Why?

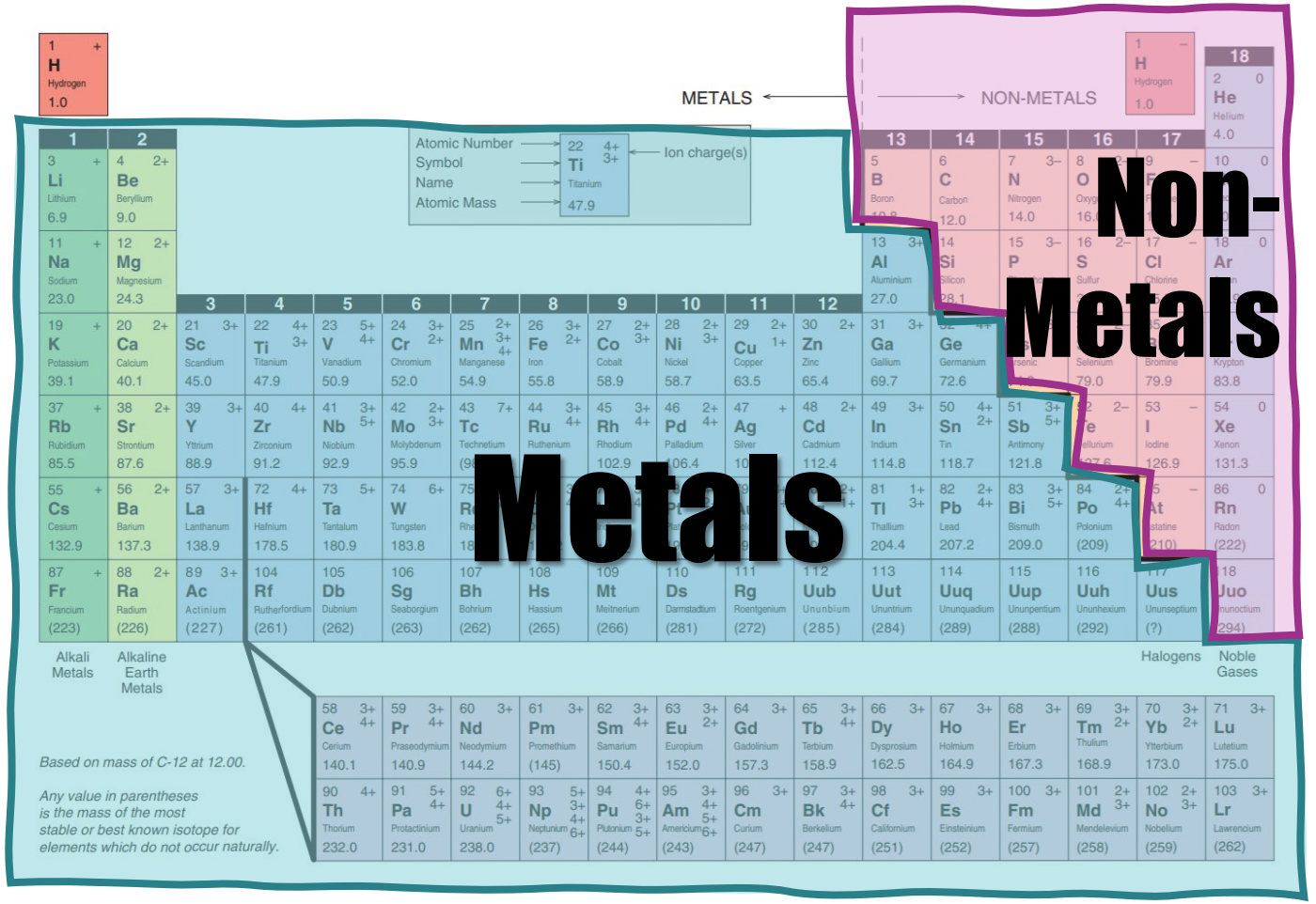
- Scientists can communicate with each other and the public, even in different languages
- Every compound has a unique name
- Information/records are accurate and consistent

IUPAC (International Union of Pure and Applied Chemistry) came up with a naming scheme that is used around the world.

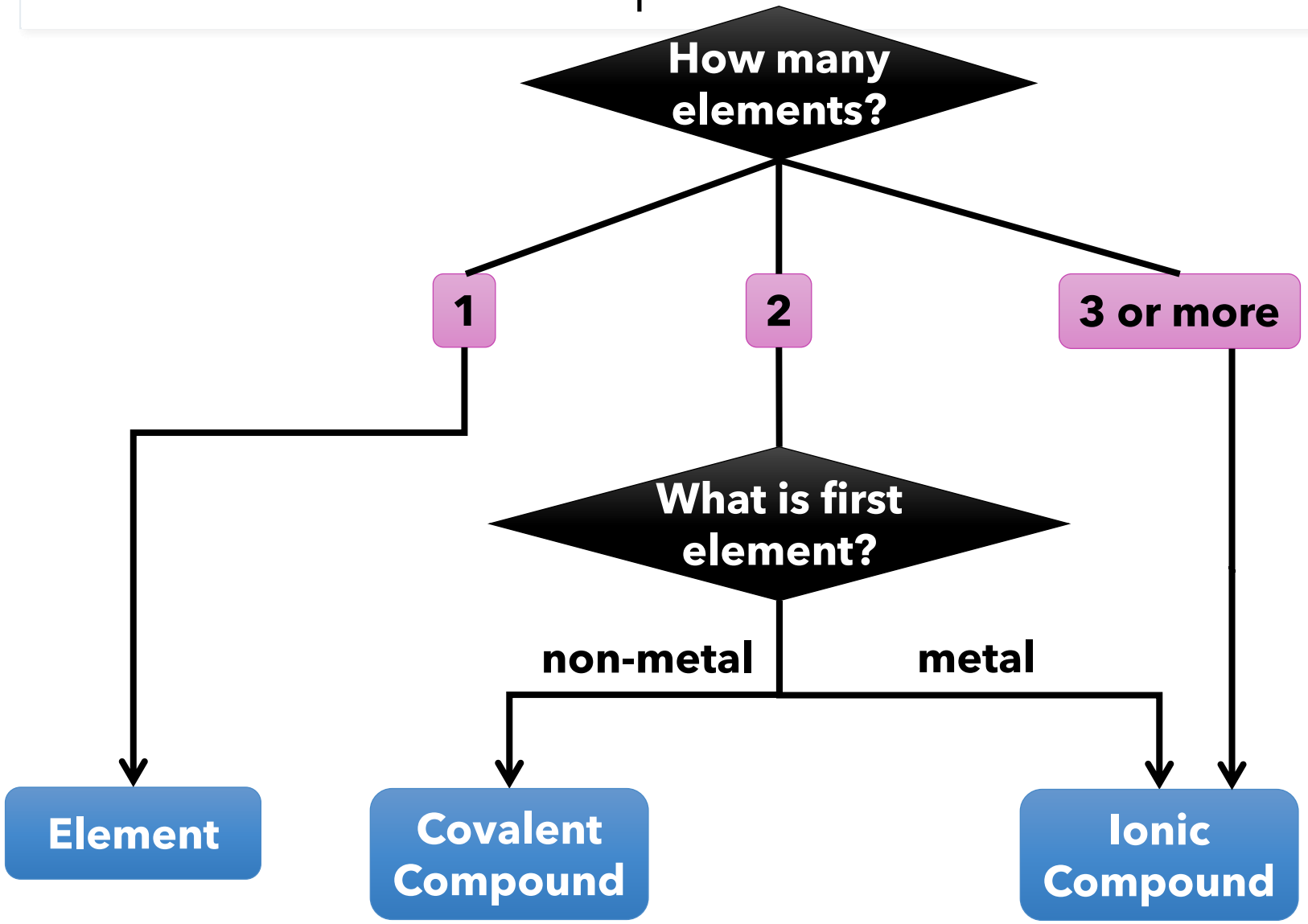
Identifying Elements, Ionic Compounds, and Covalent Compounds

Identifying Elements, Ionic Compounds, Covalent Compounds

- **Ionic compounds** form when **electrons are transferred** and ions are formed. Usually involves a **metal** and a **non-metal**.
- **Covalent compounds** form when two (or more) **non-metal** atoms **share electrons**.



Identifying Elements, Ionic Compounds, Covalent Compounds



In Science 9 and 10, you can use the following flowchart to tell apart elements and compounds based on their formulas.

(Note: in nature, many covalent compounds with 3+ elements exist; but we will not learn how to name them.)

The CI Conundrum

Sometimes, CI and CI can look alike. Usually, it will refer to chlorine. Rarely, it will refer to carbon and iodine. When in doubt, ask!

$NaCl$

$MgClO_4$

Cl_2

CI_4

Identifying Elements, Ionic Compounds, Covalent Compounds

Chemical	What is it?	Chemical	What is it?
PF_3		Mg	
$CaCl_2$		NaOH	
Cl_2		CCl_4	
NO_2		$MgBr_2$	
Br_2			

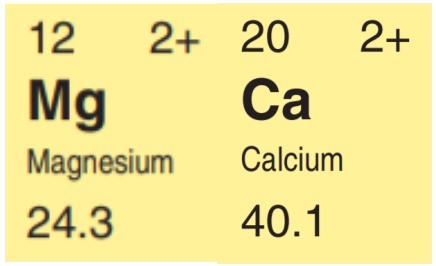
Naming Elements

Naming Elements

An **element** is a pure substance containing **only one kind of atom**.

Examples:

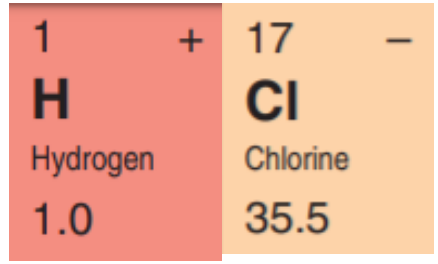
- Mg (magnesium)
- Ca (calcium)



Names of elements are found on the **periodic table**.

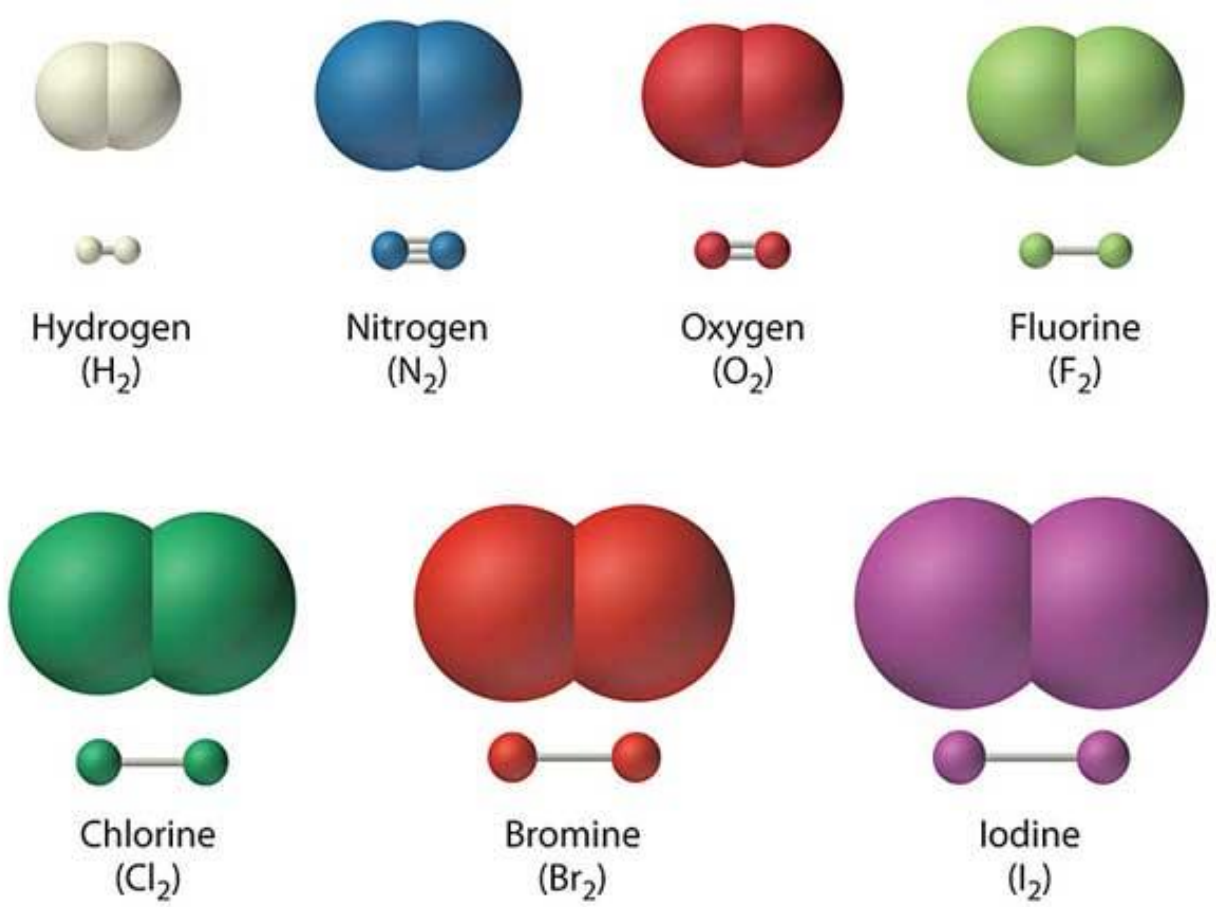
Ignore subscripts when naming.

- H_2 (hydrogen)
- Cl_2 (chlorine)



Revisiting Diatomic Elements

- When in their elemental (i.e. not in a compound) form, these elements exist as **diatomic molecules**: two atoms bonding covalently to fill their valence shells.
- Must memorize!



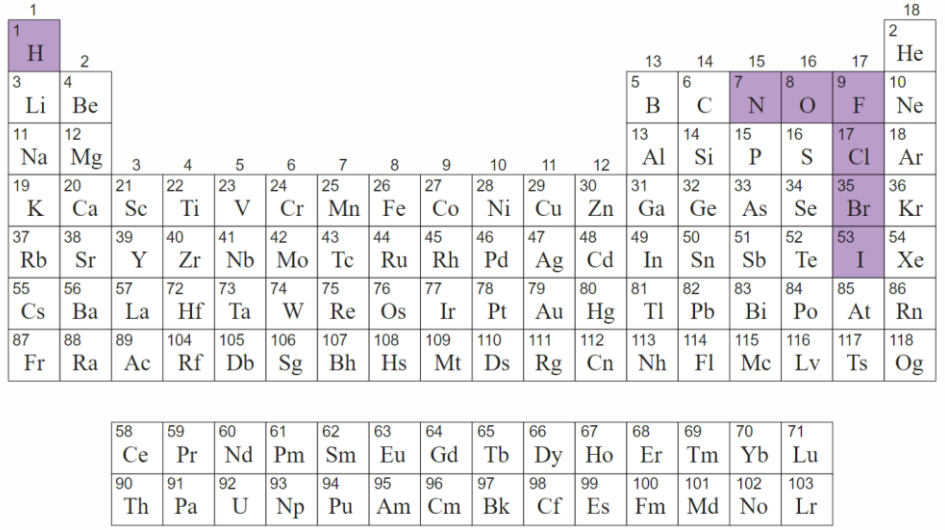
https://fl-pda.org/independent/courses/elementary/science/section4/4c6.htm

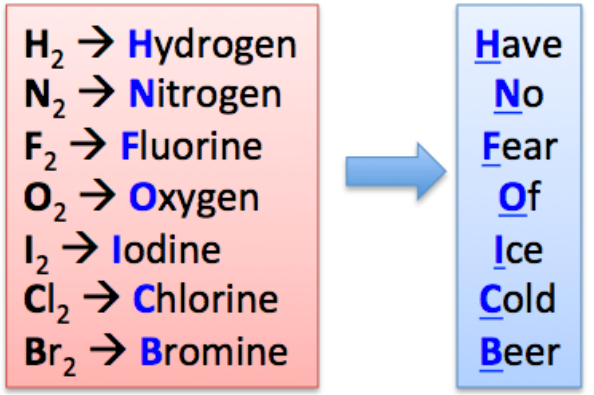
Revisiting Diatomic Elements

Memory aids:

- **HIBrONClF**
- **HOFBrINCl**
- **I Have No Bright Or Clever Friends**
- **Have No Fear Of Ice Cold Beer**
- **I Bring Cookies For Our New Home**

…or make your own!





https://study.com/academy/lesson/diatomic-molecule-definition-example.html https://mccord.cm.utexas.edu/chembook/page-nonav.php?chnum=1&sect=12

Naming Elements

1) Write the names of the following elements.

a. Na	sodium	e. O_2	oxygen
b. Br_2	bromine	f. Cu	copper
c. Mn	manganese	g. Ti	titanium
d. F_2	fluorine	h. Sr	strontium

2) Write the formulas of the following elements.

a. carbon	C	e. iodine	I_2
b. chromium	Cr	f. potassium	K
c. hydrogen	H_2	g. phosphorus	P
d. helium	He	h. chlorine	Cl_2

Naming Ions

(not covered in textbook)

Reference

Non-metal Element	"-ide" Ending
N, nitrogen	**Nitride**
O, oxygen	**Oxide**
F, fluorine	**Fluoride**
P, phosphorus	**Phosphide**
S, sulfur	**Sulfide**

Non-metal Element	"-ide" Ending
Cl, chlorine	**Chloride**
Se, selenium	**Selenide**
Br, bromine	**Bromide**
I, iodine	**Iodide**
H, hydrogen	**Hydride**

Non-metal Element	"-ide" Ending
As, arsenic *	**Arsenide**
Te, tellurium *	**Telluride**
At, astatine *	**Astatide**

* uncommon

Different Types of Ions (Monovalent)

Monovalent ion:

- Can only make one ion (see periodic table)
- Cations: write name of element
- Anions: write name of element with "–ide" ending

Examples:

- Sodium ion = Na^{+}
- Yttrium ion = Y^{3+}
- Bromide ion = Br^{-}
- Oxide ion = O^{2-}

Different Types of Ions

Multivalent Ion:

- An element that can make *multiple possible ions* (see periodic table)
- Metals only
- Must specify charge with Roman numerals

Examples:

- manganese(III) = Mn^{3+}
- manganese(IV) = Mn^{4+}
- copper(I) = Cu^{+}
- vanadium(V) = V^{5+}

Note: manganese and magnesium are *different* elements!

Different Types of Ions

Polyatomic ion:

- Group of non-metal atoms *covalently* bonded with an ionic charge
- Spelling counts!!! (Copy from table)

Examples:

- NH_4^+ = ammonium ion
- PO_4^{3-} = phosphate ion
- PO_3^{3-} = phosphite ion

Polyatomic Ions

Note: Become familiar with these names so you can recognize them quickly in the future.

NAMES, FORMULAE AND CHARGES OF SOME POLYATOMIC IONS

Positive Ions	Negative Ions	
NH_4^+ Ammonium	CH_3COO^-	Acetate
	CO_3^{2-}	Carbonate
	ClO_3^-	Chlorate
	ClO_2^-	Chlorite
	CrO_4^{2-}	Chromate
	CN^-	Cyanide
	$Cr_2O_7^{2-}$	Dichromate
	HCO_3^-	Hydrogen carbonate, bicarbonate
	HSO_4^-	Hydrogen sulfate, bisulfate
	HS^-	Hydrogen sulfide, bisulfide
	HSO_3^-	Hydrogen sulfite, bisulfite
	OH^-	Hydroxide
	ClO^-	Hypochlorite
	NO_3^-	Nitrate
	NO_2^-	Nitrite
	ClO_4^-	Perchlorate
	MnO_4^-	Permanganate
	PO_4^{3-}	Phosphate
	PO_3^{3-}	Phosphite
	SO_4^{2-}	Sulfate
	SO_3^{2-}	Sulfite

Practise

1) Write the names of the following monovalent ions.

a. Mg^{2+} magnesium
b. S^{2-} sulfide
c. Br^{-} bromide
d. K^{+} potassium
e. O^{2-} oxide
f. N^{3-} nitride
g. Na^{+} sodium
h. Sc^{3+} scandium

2) Write the names of the following multivalent ions.

a. Fe^{2+} iron(II)
b. Fe^{3+} iron(III)
c. Cu^{2+} copper(II)
d. Sn^{4+} tin(IV)
e. Au^{3+} gold(III)
f. Au^{1+} gold(I)
g. Ti^{4+} titanium(IV)
h. Mn^{3+} manganese(III)

Practise

3) Write the names of the following polyatomic ions.

a. CN^- cyanide
b. ClO_4^- perchlorate
c. NO_3^- nitrate
d. MnO_4^- permanganate
e. HSO_4^- bisulfate
f. PO_4^{3-} phosphate
g. OH^- hydroxide
h. NH_4^+ ammonium

4) What is the charge of each of the following polyatomic ions?

a. dichromate 2-
b. carbonate 2-
c. bisulfide 1-
d. phosphite 3-
e. sulfate 2-
f. sulfite 2-
g. chlorite 1-
h. hydrogen carbonate 1-

Practise

5) Name each of the following ions.

a. Co^{3+} cobalt(III)
b. Be^{2+} beryllium
c. S^{2-} sulfide
d. Cr^{2+} chromium(II)
e. CrO_4^{2-} chromate
f. P^{3-} phosphide
g. V^{5+} vanadium(V)
h. OH^- hydroxide

Remember: Roman numerals for multivalent metals ONLY.

Ionic Compound Nomenclature

(not covered in textbook)

Intro to Ionic Compound Nomenclature

Cation comes first; anion comes second.

Names of ionic compounds tell you *which ions* are in the compound.

e.g. "sodium chloride" has Na^+ and Cl^- ions.

e.g. "titanium(IV) dichromate" has Ti^{4+} and $Cr_2O_7^{2-}$ ions.

Chemical formulae tell you *how many of each ion* are in the compound, using subscripts.

e.g. "$CaCl_2$" has 1 Ca^{2+} ion and 2 Cl^- ions.

e.g. "$Mn(OH)_2$" has 1 Mn^{4+} ion and 2 OH^- ions.

Naming Ionic Compounds

1. Write the **cation**, first.

   For metals that can only form one ion (monovalent metals), do not write the ion charge.

   For multivalent metals, determine the ion charge through **charge balancing**. Then, put the ion charge in **Roman numerals**, in brackets.

   If the cation is polyatomic, write it exactly the way it is written in the table.

2. Write the anion with **"-ide" ending** (unless it is polyatomic).

Naming Ionic Compounds

1. Write the **cation**, first.

   For metals that can only form one ion (monovalent metals), do not write the ion charge.

   For multivalent metals, determine the ion charge through **charge balancing**. Then, put the ion charge in **Roman numerals**, in brackets.

   If the cation is polyatomic, write it exactly the way it is written in the table.

2. Write the anion with **"–ide" ending** (unless it is polyatomic).

Naming Ionic Compounds

1. Write the ***cation, first***.
2. Write the ***anion with "-ide" ending***.

Chemical Formula	Periodic Table		Name
NaCl	11 + **Na** Sodium 23.0	17 − **Cl** Chlorine 35.5	
$MgBr_2$	12 2+ **Mg** Magnesium 24.3	35 − **Br** Bromine 79.9	

Your Turn!

Name the following ionic compounds with monovalent metals.

a) KI **potassium iodide**

b) Be_3P_2 **beryllium phosphide**

c) ZnO **zinc oxide**

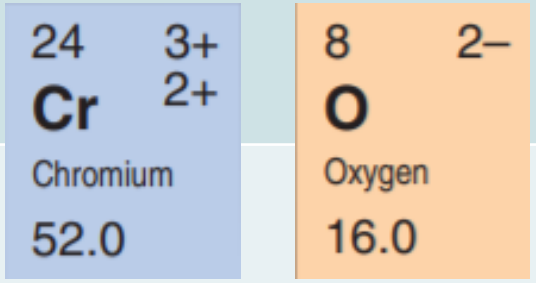
d) BaF_2 **barium fluoride**

e) $AlBr_3$ **aluminium bromide**

Naming Ionic Compounds

Oh no! Chromium is multivalent. Charge balancing is used to find the charge of a **multivalent metal ion.**

1. Write the ***cation, first***.
2. Write the ***anion with "-ide" ending***.

Chemical Formula	Periodic Table	Name
Cr_2O_3		???
CrO		???

Naming Ionic Compounds

1. Write the cation, first.

   For metals that can only form one ion (monovalent metals), do not write the ion charge.

   For multivalent metals, determine the ion charge through ***charge balancing***. Then, put the ion charge in ***Roman numerals***, in brackets.

2. Write the anion with "–ide" ending.

Charge Balancing (to find the charge of a **multivalent** metal ion)

1) Write out all the ions you have. Leave the charge blank on the multivalent metal.
2) Rule: *The total number of **positive** charges in an ionic compound must equal the total number of **negative** charges. Determine the charge on the metal ion.*
3) Write the compound name. Specify the ion charge on the multivalent metal using brackets and Roman numerals.

Charge Balancing Part 1: Determining Charges of Multivalent Metals

24 3+ 2+
Cr
Chromium
52.0

8 2–
O
Oxygen
16.0

Cr_2O_3:	
1) Write out all the ions you have. Leave the charge blank on the multivalent metal.	$Cr^{?}$ O^{2-} $Cr^{?}$ O^{2-} O^{2-} We know there are 2 chromium ions and 3 oxygen ions from the subscripts in the formula.
2) *The total number of positive charges in an ionic compound must equal the total number of negative charges.* Determine the charge on the metal ion.	Total: 6 negative charges. Must have 6 positive to balance the charges. Divide by # of chromium ions (2). Therefore, each Cr ion must have a 3+ charge.
3) Write the compound name. Specify the ion charge on the multivalent metal using brackets and Roman numerals.	**chromium(III) oxide**

Charge Balancing Part 1: Determining Charges of Multivalent Metals

24 3+ 2+
Cr
Chromium
52.0

8 2–
O
Oxygen
16.0

CrO:	
1) Write out all the ions you have. Leave the charge blank on the multivalent metal.	$Cr^{?}$ O^{2-} We know there is 1 chromium ion and 1 oxygen ion from the subscripts in the formula.
2) *The total number of positive charges in an ionic compound must equal the total number of negative charges.* Determine the charge on the metal ion.	Total: 2 negative charges. Must have 2 positive to balance the charges. Divide by # of chromium ions (1). Therefore, each Cr ion must have a 2+ charge.
3) Write the compound name. Specify the ion charge on the multivalent metal using brackets and Roman numerals.	chromium(II) oxide

Your Turn!

Name the following ionic compounds with multivalent metals.

a) TiO_2 **titanium(IV) oxide**

b) Mo_2S_3 **molybdenum(III) sulfide**

c) Hg_3P **mercury(I) phosphide**

d) $MnSe_2$ **manganese(IV) selenide**

e) SnI_2 **tin(II) iodide**

Your Turn!

Name the following ionic compounds. Make sure you do charge balancing for ionic compounds with multivalent metals only.

1) Who wants to take a $\mathbf{Na_3P}$?

2) Better **FeS** up.

3) Is your name $\mathbf{Be_3N_2}$?

4) Who $\mathbf{AmI_6}$?

5) "Vegetable" in Chinese is $\mathbf{CaI_2}$.

Your Turn!

Name the following ionic compounds. Make sure you do charge balancing for ionic compounds with multivalent metals only.

1) Who wants to take a **Na_3P**? **sodium phosphide**

2) Better **FeS** up. **iron(II) sulfide**

3) Is your name **Be_3N_2**? **beryllium nitride**

4) What about **AmI_6**? **americium(VI) iodide**

5) "Vegetable" in Chinese is **CaI_2**. **calcium iodide**

Naming Ionic Compounds

1. Write the cation, first.

   For metals that can only form one ion (monovalent metals), do not write the ion charge.

   For multivalent metals, determine the ion charge through charge balancing. Then, put the ion charge in Roman numerals, in brackets.

   If the cation is polyatomic, write it exactly the way it is written in the table.

2. Write the anion with "–ide" ending ***(unless it is polyatomic.)***

Polyatomic Ions

Note: Become familiar with these names so you can recognize them quickly in the future.

NAMES, FORMULAE AND CHARGES OF SOME POLYATOMIC IONS

Positive Ions	Negative Ions
NH_4^+ Ammonium	CH_3COO^- Acetate
	CO_3^{2-} Carbonate
	ClO_3^- Chlorate
	ClO_2^- Chlorite
	CrO_4^{2-} Chromate
	CN^- Cyanide
	$Cr_2O_7^{2-}$ Dichromate
	HCO_3^- Hydrogen carbonate, bicarbonate
	HSO_4^- Hydrogen sulfate, bisulfate
	HS^- Hydrogen sulfide, bisulfide
	HSO_3^- Hydrogen sulfite, bisulfite
	OH^- Hydroxide
	ClO^- Hypochlorite
	NO_3^- Nitrate
	NO_2^- Nitrite
	ClO_4^- Perchlorate
	MnO_4^- Permanganate
	PO_4^{3-} Phosphate
	PO_3^{3-} Phosphite
	SO_4^{2-} Sulfate
	SO_3^{2-} Sulfite

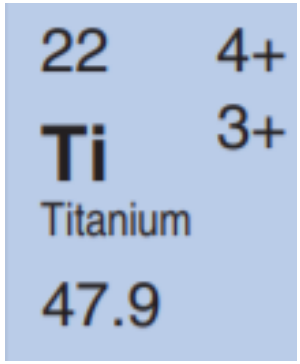
Naming with Polyatomic Ions: Examples

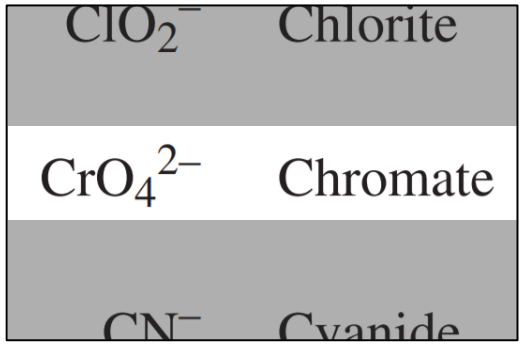
Chemical Formula	Periodic Table	Name
$Mg(OH)_2$	12 2+ **Mg** Magnesium 24.3 HSO_3^- Hydrogen sulfite, bisulfite OH^- Hydroxide ClO^- Hypochlorite	magnesium hydroxide
$(NH_4)_2S$	**Positive Ions** NH_4^+ Ammonium 16 2– **S** Sulfur 32.1	ammonium sulfide

Naming with Polyatomic Ions: Examples

Chemical Formula	Periodic Table	Name
$Sc(HSO_3)_3$	21 3+ **Sc** Scandium 45.0 HSO_4^- Hydrogen sulfate, bisulfate HS^- Hydrogen sulfide, bisulfide HSO_3^- Hydrogen sulfite, bisulfite	1. scandium hydrogen sulfite *OR* 2. scandium bisulfite ~~scandium hydrogen sulfite, bisulfite~~

Naming with Polyatomic Ions: Examples





$Ti_2(CrO_4)_3$:	
1) Write out all the ions you have. Leave the charge blank on the multivalent metal.	$Ti^?$ CrO_4^{2-} CrO_4^{2-} $Ti^?$ CrO_4^{2-}
2) *The total number of positive charges in an ionic compound must equal the total number of negative charges.* Determine the charge on the metal ion.	Total: 6 negative charges. Must have 6 positive to balance the charges. Divide by # of titanium ions (2). Therefore, each Ti ion must have a 3+ charge.
3) Write the compound name. Specify the ion charge on the multivalent metal using brackets and Roman numerals. Spell the polyatomic ion exactly as it is spelled in the reference sheet.	titanium(III) chromate

Your Turn!

Name the following ionic compounds with polyatomic ions.

a) $Ca(OH)_2$ **calcium hydroxide**

b) $Zn(ClO_4)_2$ **zinc perchlorate**

c) $(NH_4)_2O$ **ammonium oxide**

d) $Ti_3(PO_3)_4$ **titanium(IV) phosphite**

e) $HgHSO_4$ **mercury(I) bisulfate *or***

mercury(I) hydrogen sulfate

Writing Formulas of Ionic Compounds

(not covered in textbook)

Intro to Ionic Compound Nomenclature

Names of ionic compounds tell you *which ions* are in the compound. The cation comes first; the anion comes second.

To write a chemical formula of an ionic compound, you must find out how many of each ion is involved, through **charge balancing.**

Rule: The total number of positive charges in an ionic compound must equal the total number of negative charges.

Writing Formulas of Ionic Compounds (v1)

1. Write down each ion with its charge.
2. Add more of the ions to balance the charges: the total number of positive and negative charges must be equal.
3. Write your formula with subscripts.

    To indicate more than one of a polyatomic ion, use brackets with the subscript outside.

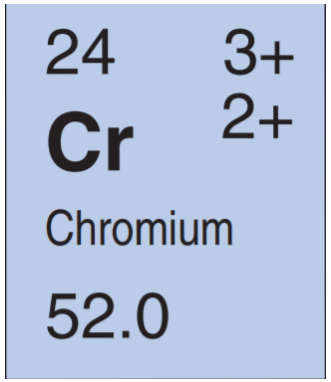
Writing Chemical Formulas: Examples (v1)

20 2+
Ca
Calcium
40.1

15 3–
P
Phosphorus
31.0

calcium phosphide	
1) Write down each ion with its charge.	Ca^{2+} P^{3-}
2) Add more of the ions to balance the charges: the total number of positive and negative charges must be equal.	Ca^{2+} P^{3-} Ca^{2+}
3) Write your formula with subscripts.	Ca_3P_2

Writing Chemical Formulas: Examples (v1)



HSO_3^-	Hydrogen sulf
OH^-	Hydroxide
ClO^-	Hypochlorite

chromium(II) hydroxide	
1) Write down each ion with its charge.	Cr^{2+} OH^- OH^-
2) Add more of the ions to balance the charges: the total number of positive and negative charges must be equal.	
3) Write your formula with subscripts.	$Cr(OH)_2$

Writing Chemical Formulas: Practice (v1)

1) Use "Version 1" to write the chemical formulas of these compounds.

a) calcium nitride Ca_3N_2

b) copper(II) iodide CuI_2

c) aluminium nitride AlN

d) manganese(IV) sulfate $Mn(SO_4)_2$

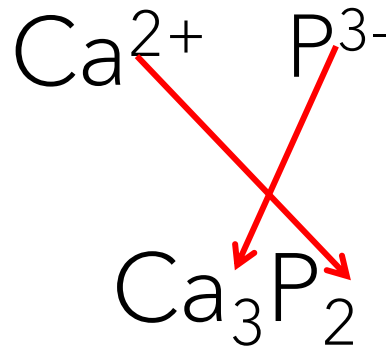
Writing Formulas of Ionic Compounds (v2)

1. Write down each ion with its charge.
2. Write the chemical formula by writing the cation first and the anion second. Then, “criss-cross” the charges to become the subscripts.
3. Reduce the subscripts if both divisible by the same number.

Writing Chemical Formulas: Examples (v2)

20 2+
Ca
Calcium
40.1

15 3–
P
Phosphorus
31.0

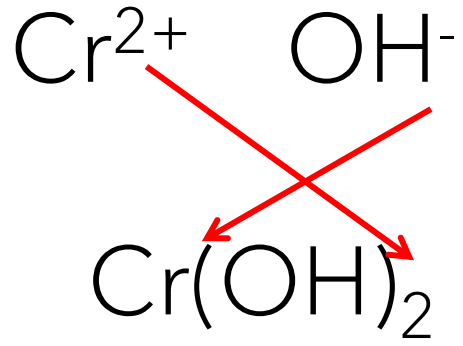
calcium phosphide	
1) Write down each ion with its charge.	
2) Write the chemical formula by writing the cation first and the anion second. Then, "criss-cross" the charges to become the subscripts.	
3) Reduce the subscripts if both divisible by the same number.	2 and 3 do not have a common factor. Therefore, Ca_3P_2 is our final answer.

Writing Chemical Formulas: Examples (v2)

24	3+ 2+
Cr	
Chromium	
52.0	

HSO_3^-	Hydrogen sulf
OH^-	Hydroxide
ClO^-	Hypochlorite

chromium(II) hydroxide

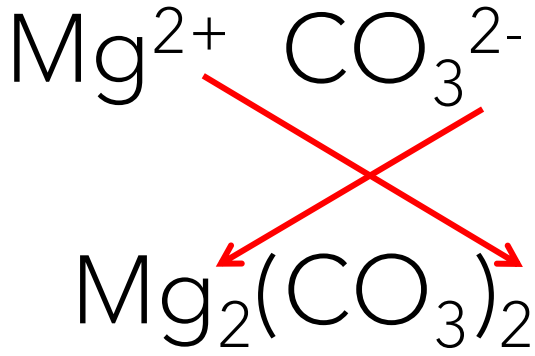
1) Write down each ion with its charge.	
2) Write the chemical formula by writing the cation first and the anion second. Then, "criss-cross" the charges to become the subscripts.	
3) Reduce the subscripts if both divisible by the same number.	1 and 2 do not have a common factor. Therefore, $Cr(OH)_2$ is our final answer.

Writing Chemical Formulas: Examples (v2)

12 2+
Mg
Magnesium
24.3

CH_3COO^-	Acetate
CO_3^{2-}	Carbonate
ClO_3^-	Chlorate

magnesium carbonate

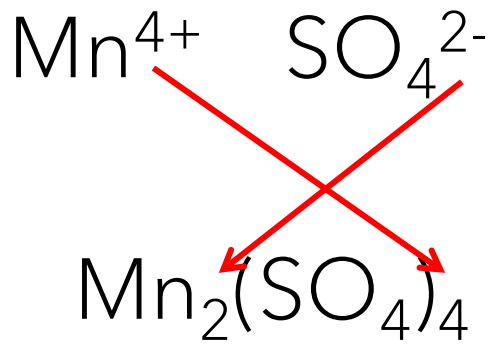
1) Write down each ion with its charge.	
2) Write the chemical formula by writing the cation first and the anion second. Then, "criss-cross" the charges to become the subscripts.	
3) Reduce the subscripts if both divisible by the same number.	2 and 2 are both divisible by 2. Rewrite formula as $MgCO_3$.

Writing Chemical Formulas: Examples (v2)

25	2+
Mn	3+
	4+
Manganese	
54.9	

PO_3^{3-}	Phosphite
SO_4^{2-}	Sulfate
SO_3^{2-}	Sulfite

manganese(IV) sulfate

1) Write down each ion with its charge.	
2) Write the chemical formula by writing the cation first and the anion second. Then, "criss-cross" the charges to become the subscripts.	
3) Reduce the subscripts if both divisible by the same number.	4 and 2 are both divisible by 2. Rewrite formula as $Mn(SO_4)_2$.

Writing Chemical Formulas: Practice (v1)

2) Use "Version 2" to write the chemical formulas of these compounds.

a) cadmium phosphide Cd_3P_2

b) chromium(III) oxide Cr_2O_3

c) rhodium(IV) sulfide RhS_2

d) strontium carbonate $SrCO_3$

Naming and Writing Formulas: Covalent Compounds

(not covered in textbook)

Naming Binary Covalent Compounds

Binary covalent compound: a covalent compound containing only two elements

Names and formulas of covalent compounds *both* tell you:

- Which elements?
- How many atoms of each element?

Example: **dichlorine monoxide** is Cl_2O

Prefixes Reference

PREFIXES

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

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

Naming Binary Covalent Compounds

1. Write the first element.
2. Write the second element with **"-ide" ending**.
3. Add **prefixes** to show how many of each element there is.
   - *Do not add **"mono-"** to first element.*
   - *If adding "mono-" to "-oxide", write **"monoxide"** instead.*

e.g. O_2F_2 di oxygen difluoride

e.g. PF_3 phosphorus trifluoride

e.g. N_2O di nitrogen mon oxide

Note: All compound names (covalent *and* ionic) are lowercase.

More Practice: Binary Covalent Compounds

Chemical Formula	Compound Name
S_2O_5	
Cl_3O_7	
CBr_2	
NO	
CCl_4	
P_2S_6	

Naming Binary Covalent Compounds

Covalent compounds with special names (must memorize):

NH_3 = ammonia

H_2O = water

CH_4 = methane

NH_4^+ (ammonium ion) and NH_3 (ammonia) are ***not the same!!!***

Chemical Formulas of Binary Covalent Compounds

1. Identify the elements involved. Write their **symbols**.
2. Use the **prefixes** to determine the number of each element in the compound. Write as **subscripts**.

e.g. tetraphosphorus pentaoxide

P_4O_5

e.g. nitrogen triiodide

NI_3

e.g. selenium difluoride

SeF_2

More Practice: Binary Covalent Compounds

Chemical Formula	Compound Name
	nitrogen trioxide
	triphosphorus tetraoxide
	iodine pentafluoride
	tricarbon disulfide
	boron trifluoride
	xenon hexafluoride

Resources

- Naming and Writing Chemical Formulas
  - Tyler DeWitt Videos https://www.youtube.com/user/tdewitt451/videos
  - Mr. Carman's Blog (generates quizzes) https://www.kentschools.net/ccarman/cp-chemistry/practice-quizzes/compound-naming/
  - Mr. Eisley (list of other resources to practice http://www.mreisley.com/nomenclature-practice.html
  - ChemFiesta (worksheets with answers) https://chemfiesta.org/2015/01/13/naming-worksheets/
- Balancing Chemical Equations
  - TemplateLAB (explanations and many worksheets with answers) https://templatelab.com/balancing-equations-worksheet/