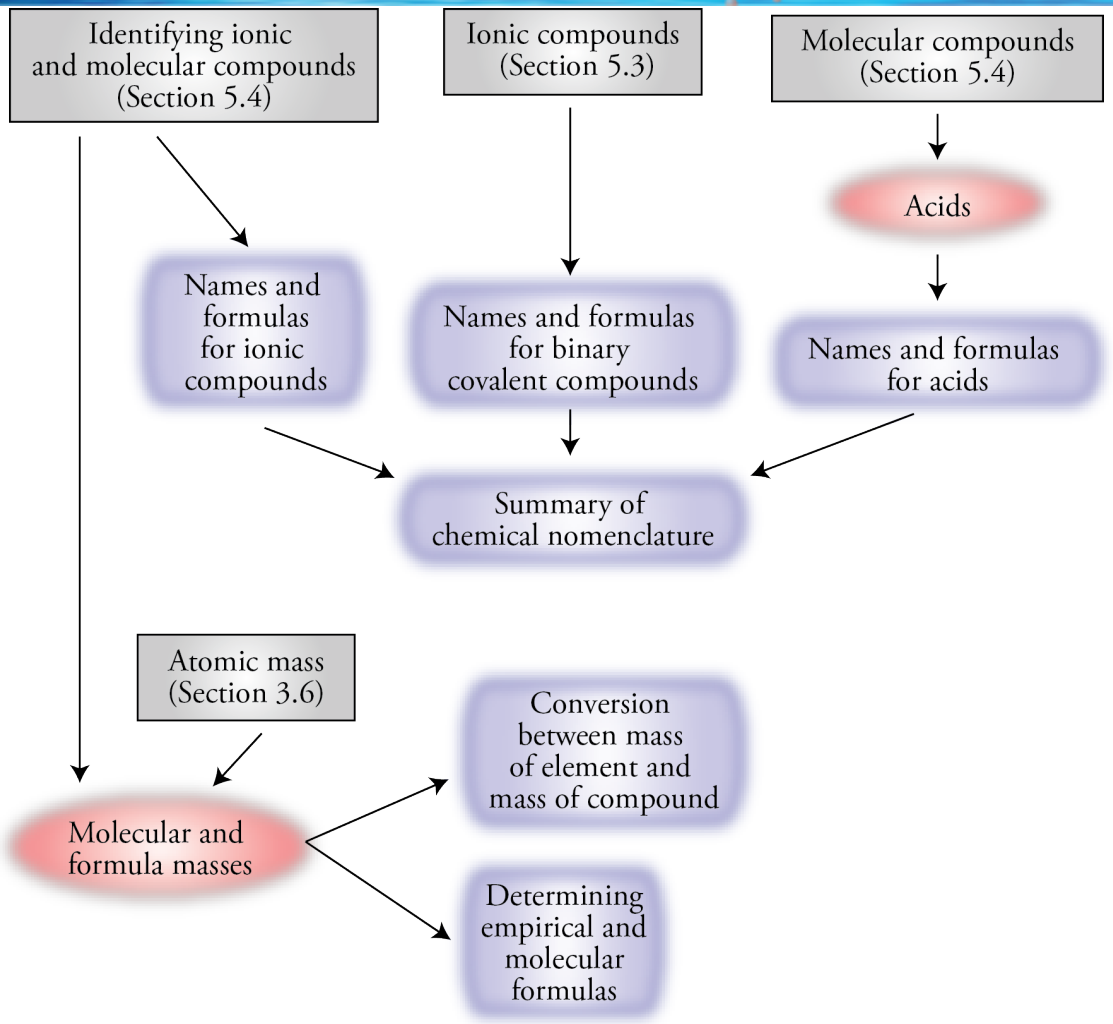
Chapter 6
More on Chemical Compounds

An Introduction to Chemistry

by Mark Bishop

Chapter Map


Identifying ionic and molecular compounds (Section 5.4)
Ionic compounds (Section 5.3)
Molecular compounds (Section 5.4)
Acids
Names and formulas for ionic compounds
Names and formulas for binary covalent compounds
Names and formulas for acids
Summary of chemical nomenclature
Atomic mass (Section 3.6)
Conversion between mass of element and mass of compound
Molecular and formula masses
Determining empirical and molecular formulas

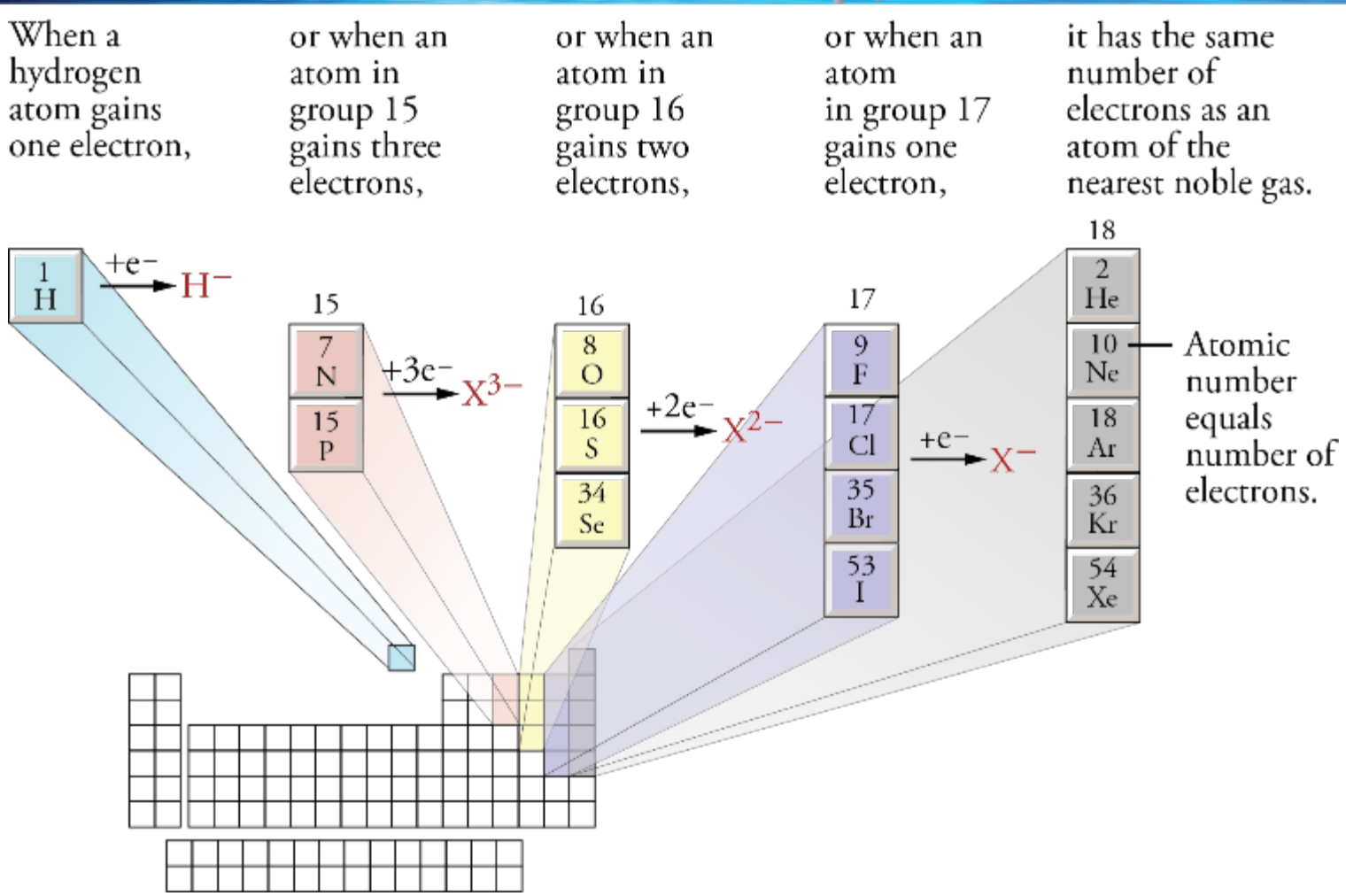
Cations and Anions

- 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.

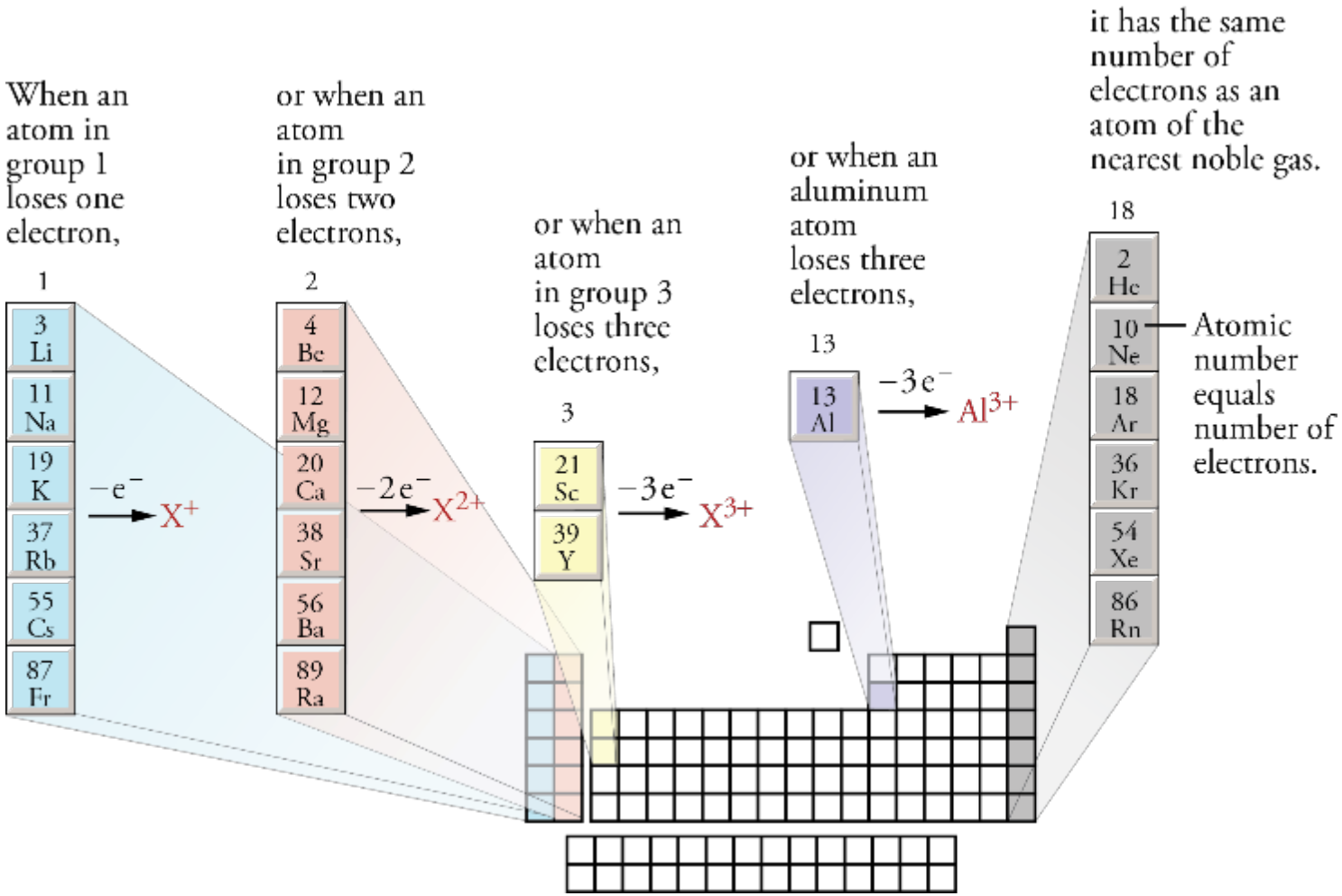
Predicting Ion Charges

- 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.

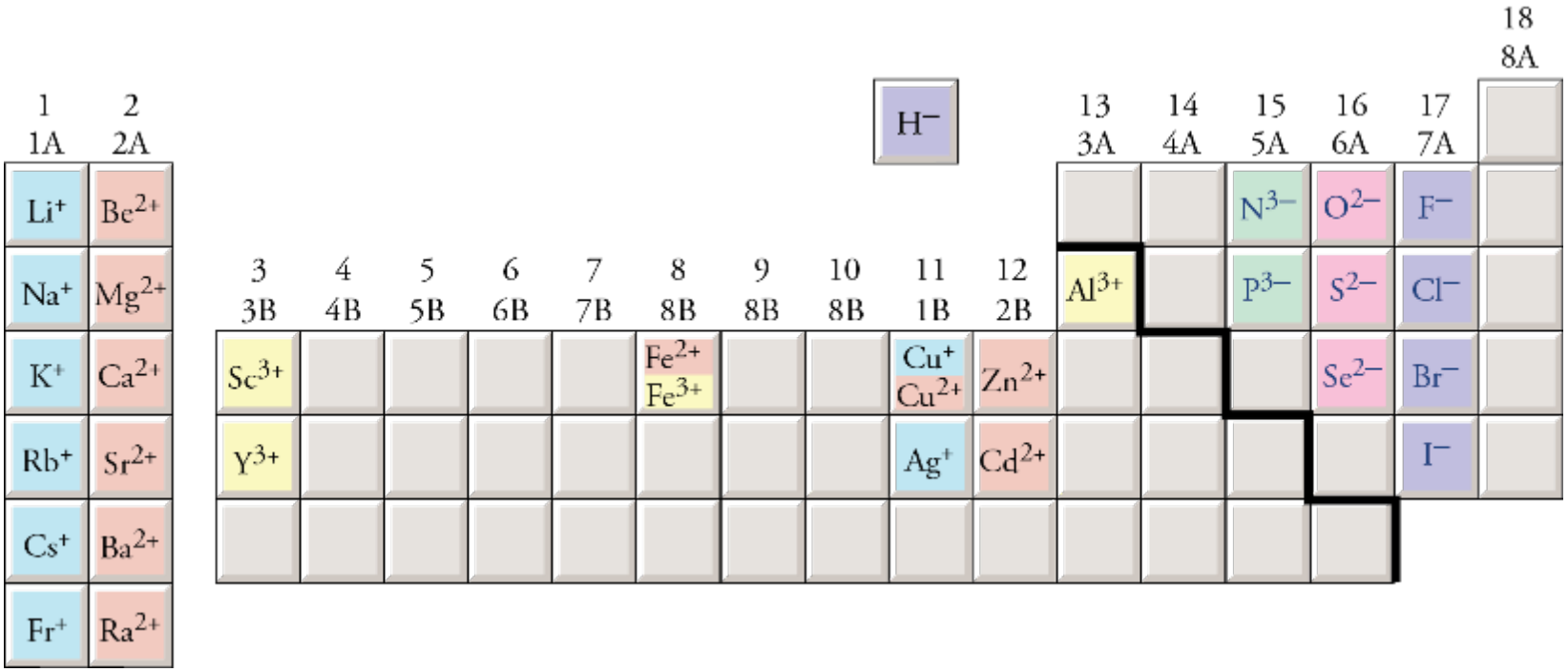
The Making of an Anion



The Making of a Cation



Monatomic Ions



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

Roots of Nonmetals

H hydr-
C carb-
N nitr-
P phosph-
O ox-
S sulf-
Se selen-

F fluor-
Cl chlor-
Br brom-
I iod-

Monatomic Anions

hydride, H^-

nitride, N^{3-}

phosphide, P^{3-}

oxide, O^{2-}

sulfide, S^{2-}

selenide, Se^{2-}

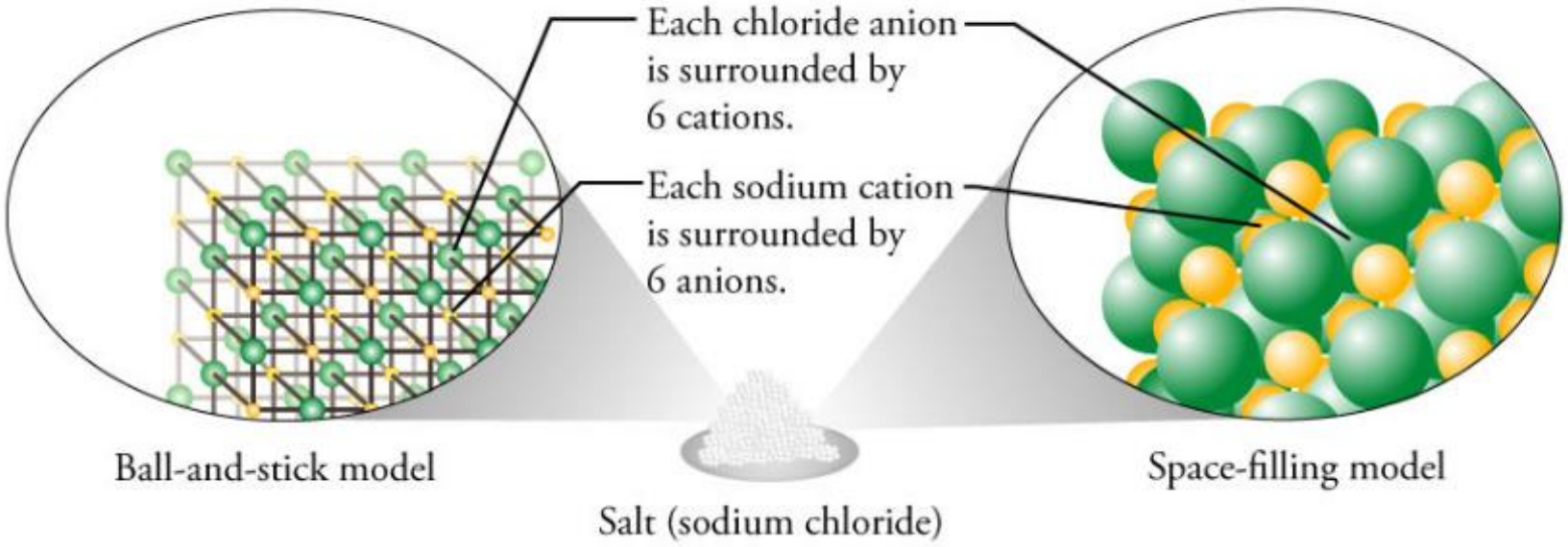
fluoride, F^-

chloride, Cl^-

bromide, Br^-

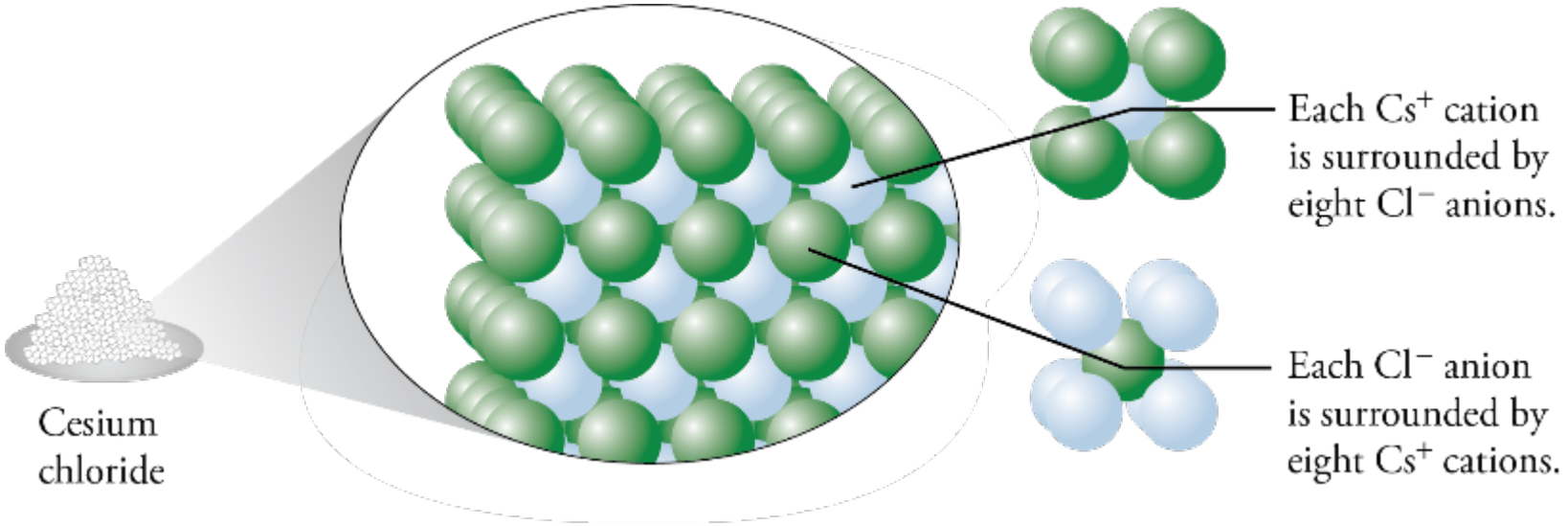
iodide, I^-

Sodium Chloride, NaCl, Structure



Cesium chloride, CsCl, Structure

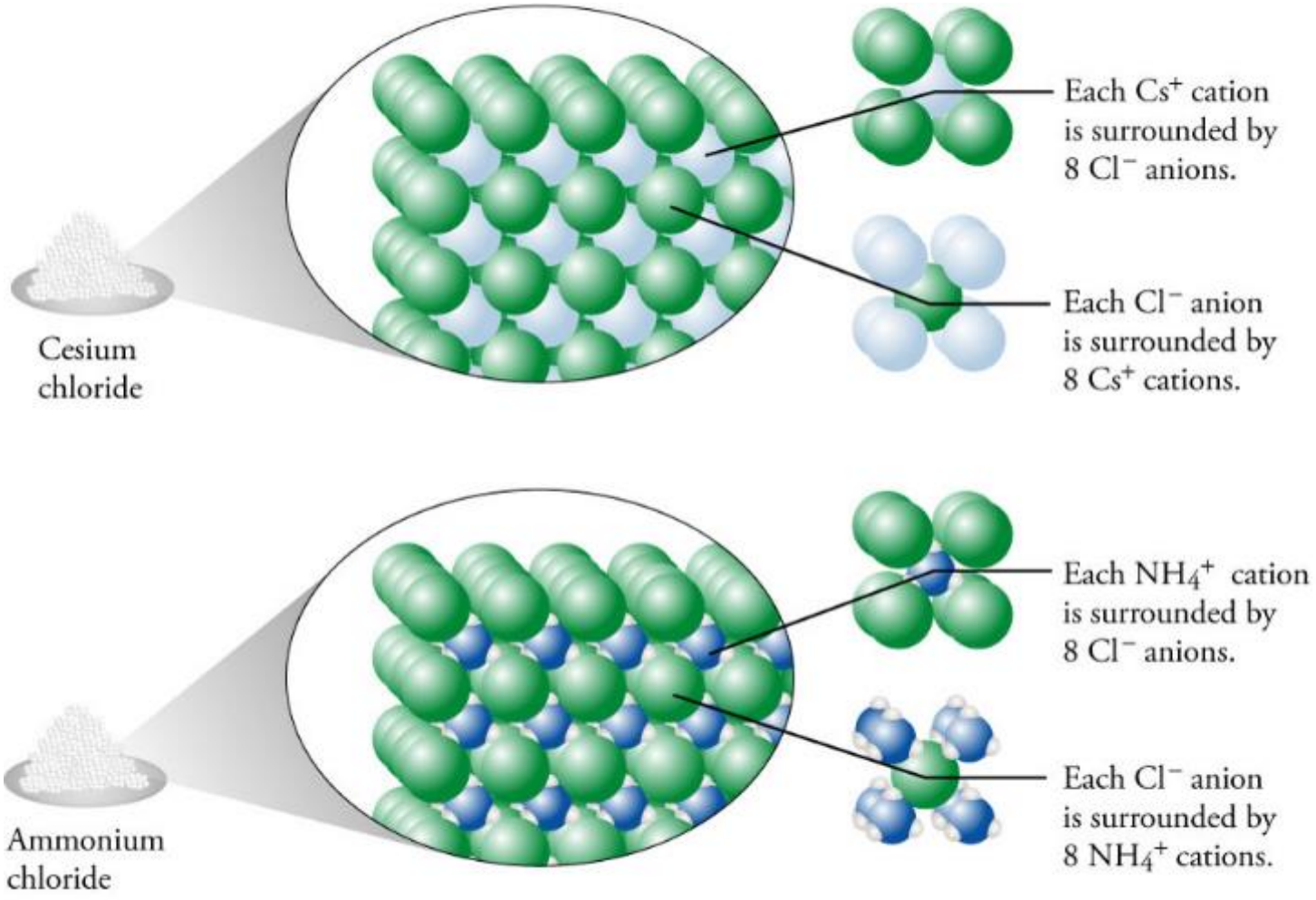
- Because the cesium ions are larger than sodium ions, there is room for eight chloride ions around each cesium ion and eight cesium ions around each chloride ion.



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 NH_4Cl structure



Polyatomic Ions

Ion	Name	Ion	Name
NH_4^+	ammonium	NO_3^-	nitrate
OH^-	hydroxide	SO_4^{2-}	sulfate
CO_3^{2-}	carbonate	$C_2H_3O_2^-$	acetate
PO_4^{3-}	phosphate		

Polyatomic Ions with Hydrogen

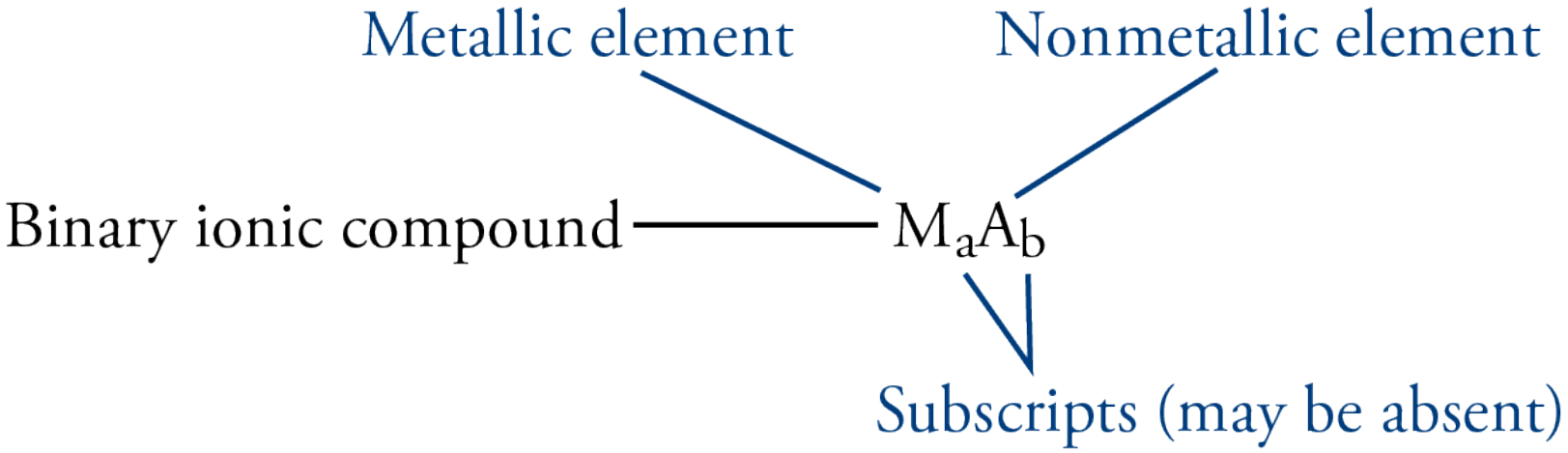
- HCO_3^- hydrogen carbonate (bicarbonate)
- HSO_4^- hydrogen sulfate
- HS^- hydrogen sulfide
- HPO_4^{2-} hydrogen phosphate
- $H_2PO_4^-$ dihydrogen phosphate

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

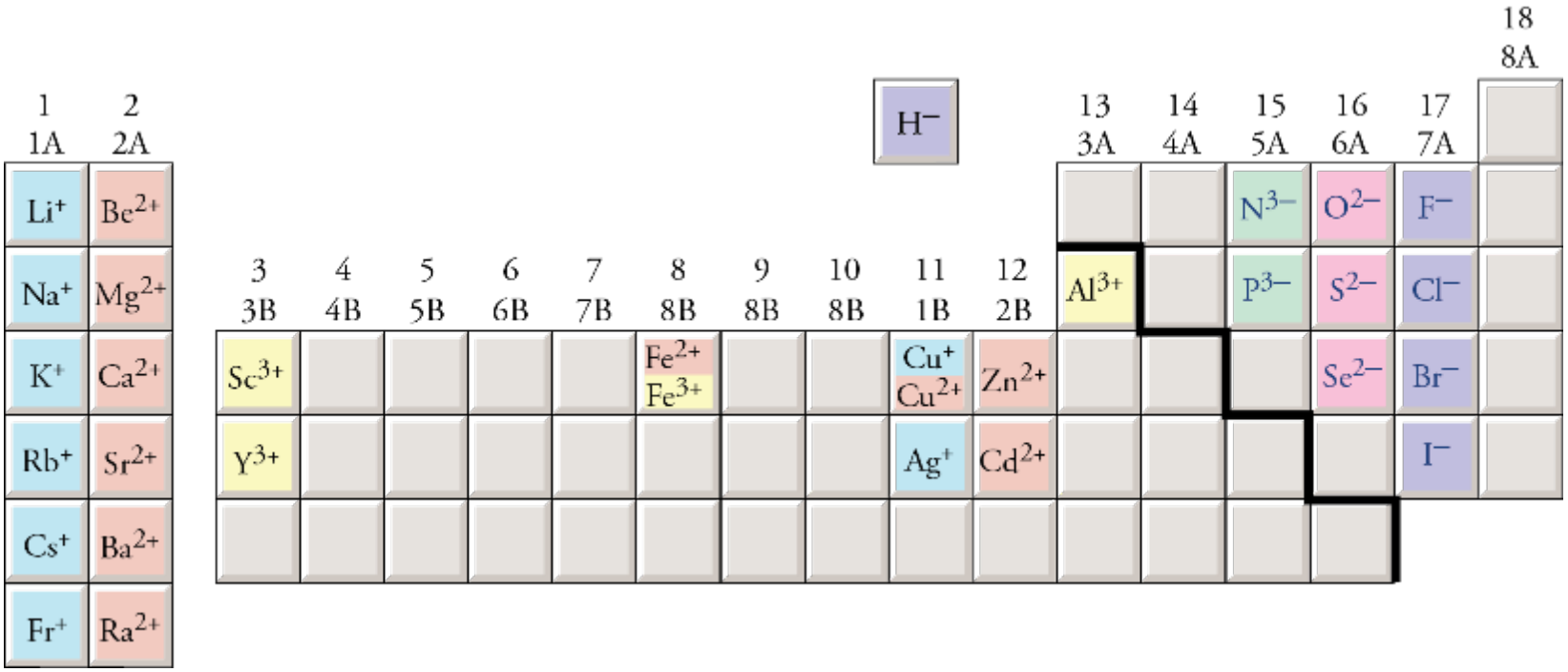
- Two steps for writing formulas for ionic compounds.
  - Determine the formula, including charge, for the cation and anion.
  - Determine the ratio of the ions that yields zero overall charge.

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



Polyatomic Ions

Ion	Name	Ion	Name
NH_4^+	ammonium	NO_3^-	nitrate
OH^-	hydroxide	SO_4^{2-}	sulfate
CO_3^{2-}	carbonate	$C_2H_3O_2^-$	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-}	$X_{\mathbf{3}}Y_2$	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-}	$X_{\mathbf{2}}Y_3$	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 **$Ca(NO_3)_2$**.

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 **$(NH_4)_2S$**.
  - 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

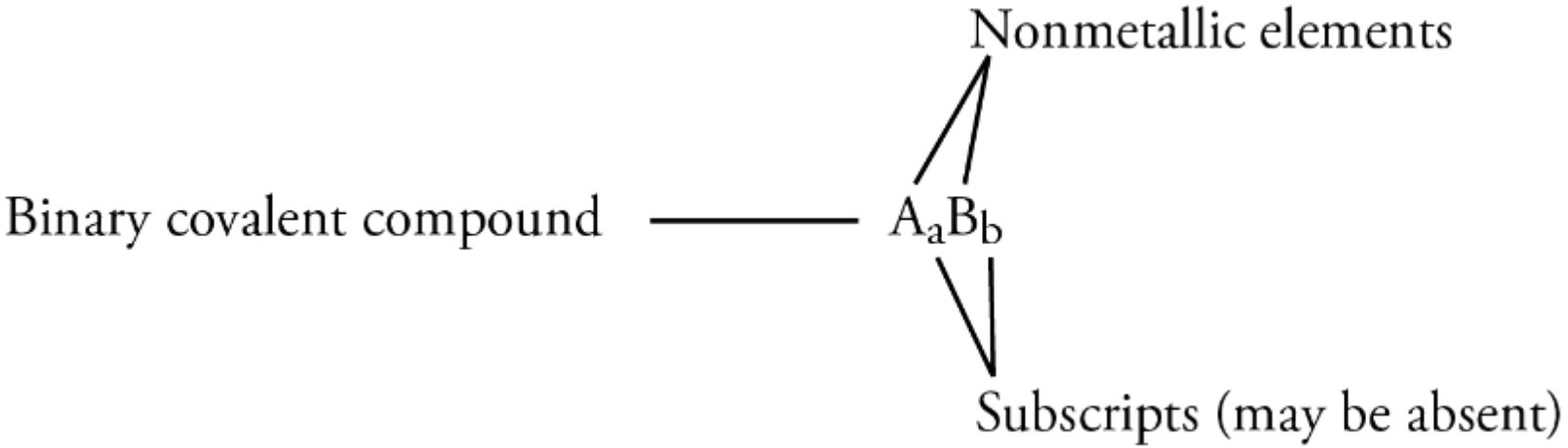
  - Conversion between anion names and formulas.

https://preparatorychemistry.com/anion_names_formulas_Canvas.html

  - Conversion between ionic compound names and formulas.

https://preparatorychemistry.com/ionic_nomenclature_Canvas.html

Binary Covalent



Common Names

- H_2O, water
- NH_3, ammonia
- CH_4, methane
- C_2H_6, ethane
- C_3H_8, propane
- C_4H_{10}, butane
- C_5H_{12}, pentane
- C_6H_{14}, hexane

Naming Binary Covalent Compounds

- If the subscript for the first element is greater than one, indicate the subscript with a prefix.
  - We do not write mono- on the first name.
  - Leave the "a" off the end of the prefixes that end in "a" and the “o” off of mono- if they are placed in front of an element that begins with a vowel (oxygen or iodine).

Prefixes

mon(o)	hex(a)
di	hept(a)
tri	oct(a)
tetr(a)	non(a)
pent(a)	dec(a)

Nitrogen Oxide Names

- N_2O_3 – name starts with *di*
- N_2O_5 – name starts with *di*
- NO_2 – no initial prefix
- NO – no initial prefix

Naming Binary Covalent Compounds

- Follow the prefix with the name of the first element in the formula.
  - N_2O_3 – *dinitrogen*
  - N_2O_3 – *dinitrogen*
  - NO_2 – *nitrogen*
  - NO – *nitrogen*

Naming Binary Covalent Compounds

- Write a prefix to indicate the subscript for the second element. (Remember to leave the “o” off of mono- and the “a” off of the prefixes that end in “a” when they are placed in front of a name that begins with a vowel.)
  - N_2O_3 – *dinitrogen tri*
  - N_2O_5 – *dinitrogen pent*
  - NO_2 – *nitrogen di*
  - NO – *nitrogen mon*

Naming Binary Covalent Compounds

- Write the root of the name of the second symbol in the formula. (See the next slide.)
  - N_2O_3 – *dinitrogen triox*
  - N_2O_5 – *dinitrogen pentox*
  - NO_2 – *nitrogen diox*
  - NO – *nitrogen monox*

Roots of Nonmetals

H hydr-
C carb-
N nitr-
P phosph-
O ox-
S sulf-
Se selen-

F fluor-
Cl chlor-
Br brom-
I iod-

Naming Binary Covalent Compounds

- Add -ide to the end of the name.
  - N_2O_3 – *dinitrogen trioxide*
  - N_2O_5 – *dinitrogen pentoxide*
  - NO_2 – *nitrogen dioxide*
  - NO – *nitrogen monoxide*

Name of Br_2O_7

- Br and O both represent nonmetallic elements, so this formula represents a binary covalent compound.
- di
- dibromine
- dibromine hept
- dibromine heptox
- dibromine heptoxide

Name of PCl_3

- P and Cl both represent nonmetallic elements, so this formula represents a binary covalent compound.
- No prefix at the beginning
- phosphorus
- phosphorus tri
- phosphorus trichlor
- phosphorus trichloride

Name of CO

- C and O both represent nonmetallic elements, so this formula represents a binary covalent compound.
- No prefix at the beginning
- carbon
- carbon mon
- carbon monox
- carbon monoxide

Name of H_2S

- H and S both represent nonmetallic elements, so this formula represents a binary covalent compound.
- di
- dihydrogen
- dihydrogen mono
- dihydrogen monosulf
- dihydrogen monosulfide
- dihydrogen sulfide or hydrogen sulfide

Binary Covalent Compounds Without Prefixes

- The following binary covalent compounds are often named without prefixes
  - HF – hydrogen fluoride
  - HCl – hydrogen chloride
  - HBr – hydrogen bromide
  - HI – hydrogen iodide
  - H_2S – hydrogen sulfide

Name NH_3

- N and H both represent nonmetallic elements, so this formula represents a binary covalent compound.
- Memorized name - ammonia

Forms of Binary Covalent Names

- prefix(name of nonmetal) prefix(root of name of nonmetal)ide

  (for example, dinitrogen pentoxide)
- or (name of nonmetal) prefix(root of name of nonmetal)ide

  (for example, carbon dioxide)
- or (name of nonmetal) (root of nonmetal)ide

  (for example, hydrogen fluoride)

Writing Binary Covalent Formulas

- If the name is a memorized name that is not a systematic name, just write the memorized formula.
- Write the symbols for the elements in the order mentioned in the name.
- Write subscripts indicated by the prefixes. If the first part of the name has no prefix, assume it is mono-.

Converting from Names to Formulas

- dinitrogen tetroxide
  - N_2O_4
- phosphorus tribromide
  - PBr_3
- hydrogen iodide
  - HI
- Methane
  - CH_4

Converting between Binary Covalent Formulas and Names

- There is a tool on the textbook's website that will allow you to practice this task.

https://preparatorychemistry.com/binary_covalent_nomenclature_Canvas.html

Arrhenius Acid Definition

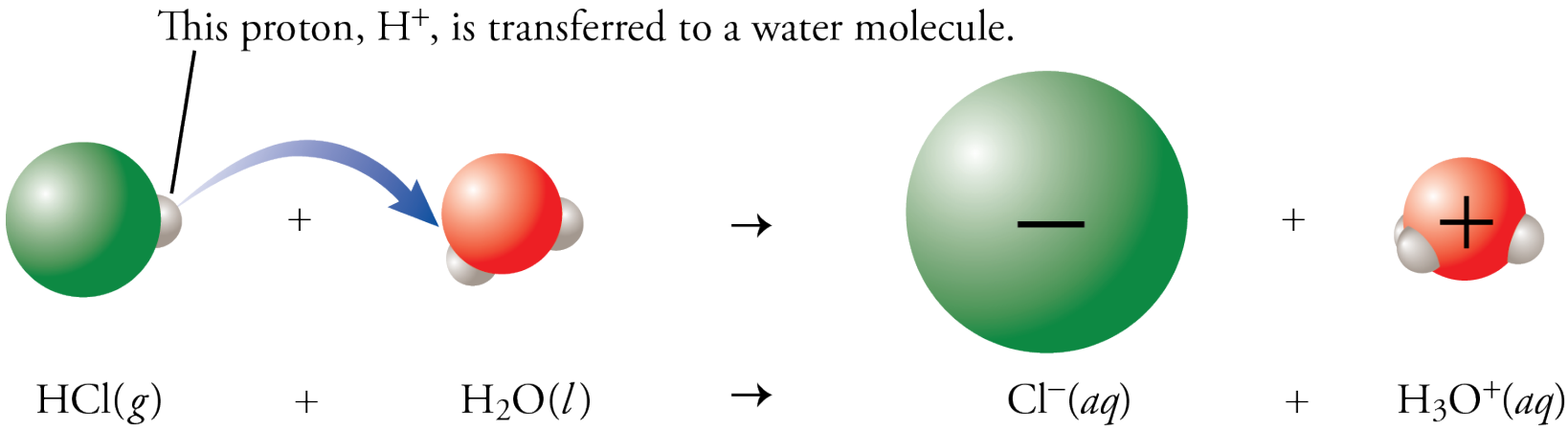
- An ***acid*** is a substance that generates hydronium ions, H_3O^+ (often described as H^+), when added to water.
- An ***acidic solution*** is a solution with a significant concentration of H_3O^+ ions.

Characteristics of Acids

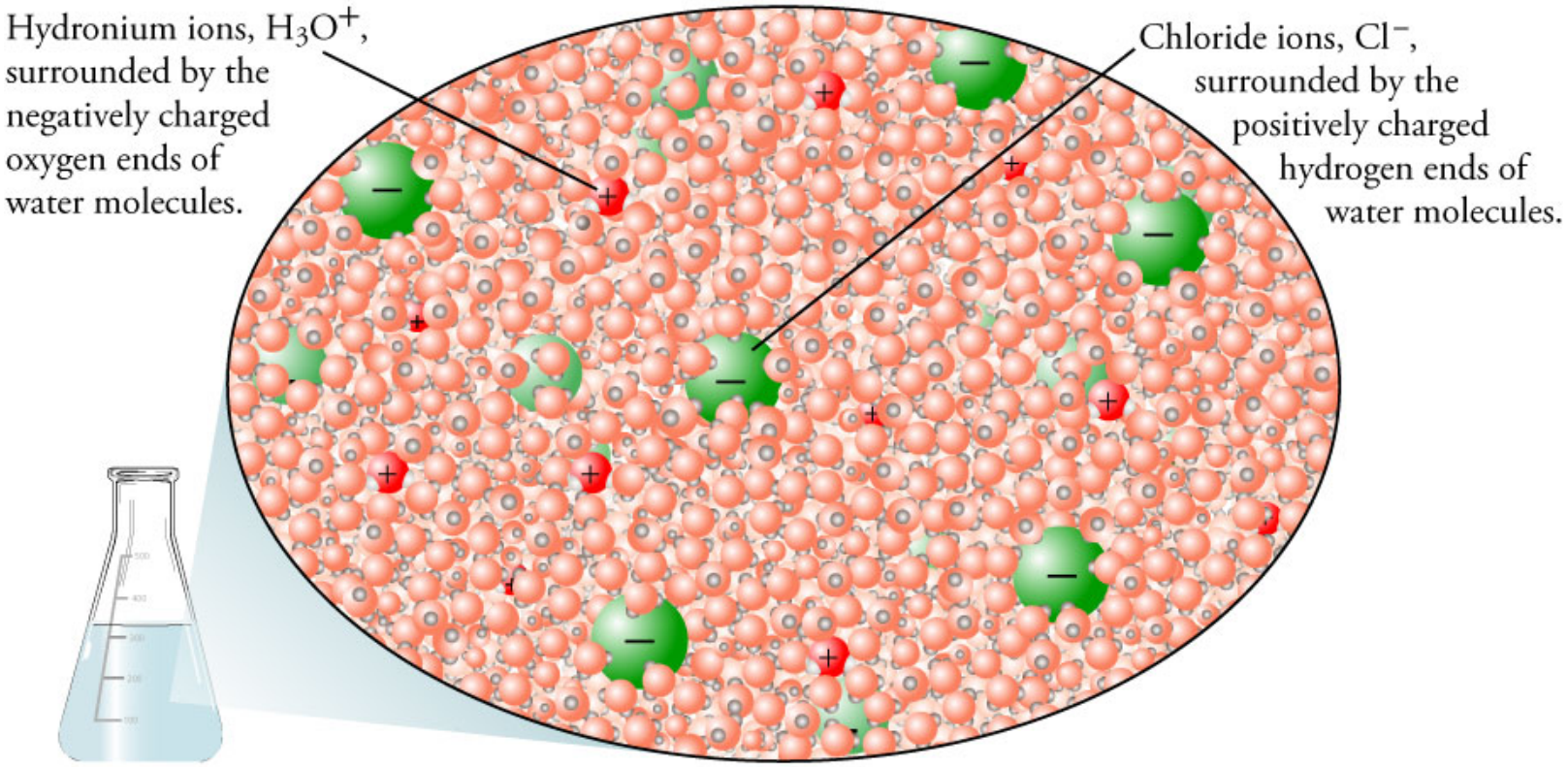
- Acids have a sour taste.
- Acids turn litmus from blue to red.
- Acids react with bases.

Strong Acid and Water

When HCl dissolves in water, hydronium ions, H_3O^+, and chloride ions, Cl^-, ions form.



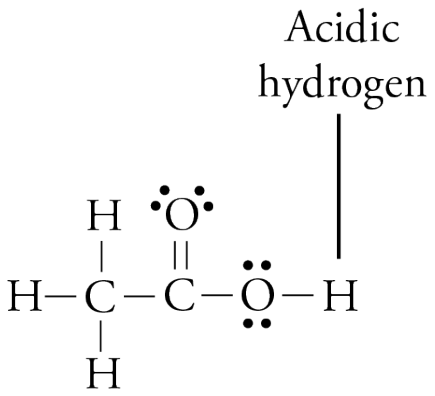
Solution of a Strong Acid

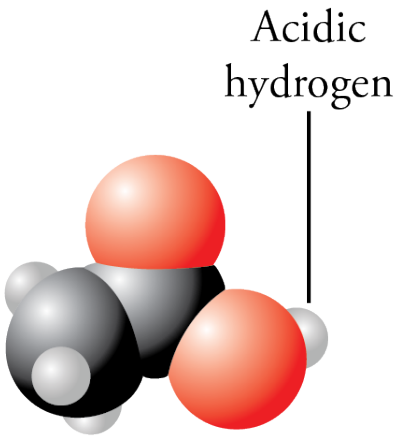


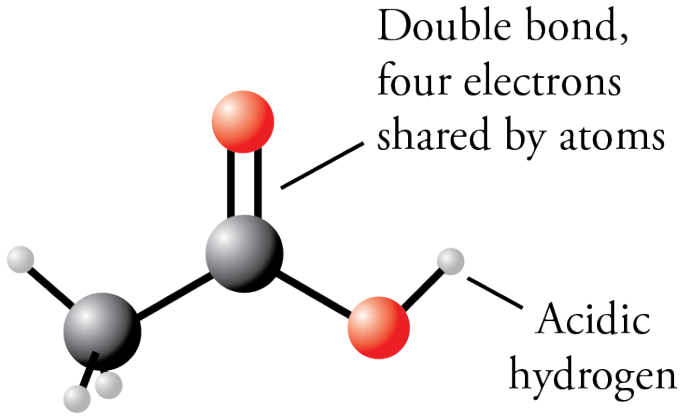
Types of Acids

- Binary acids have the general formula of HX(aq)
  - HF(*aq*) and HCl(*aq*)
- Oxyacids have the general formula $H_aX_bO_c$.
  - HNO_3 and H_2SO_4
- Organic acids, which are also called carbon-based acids or carboxylic acids
  - $HC_2H_3O_2$

Acetic Acid


Acidic
hydrogen
H
O
H—C—C—O—H
H


Acidic
hydrogen

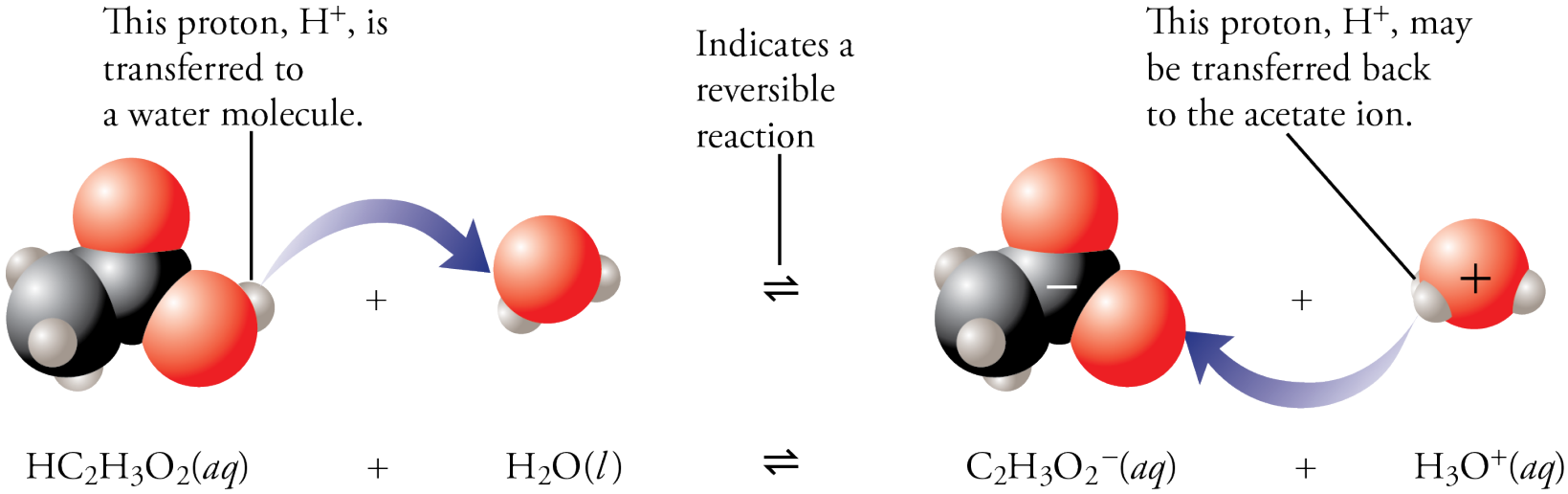

Double bond,
four electrons
shared by atoms
Acidic
hydrogen

Monoprotic and Polyprotic Acids

- If each molecule of an acid can donate one hydrogen ion, the acid is called a **monoprotic acid**.
- If each molecule can donate two or more hydrogen ions, the acid is a **polyprotic acid**.
- A **diprotic acid**, such as sulfuric acid, H_2SO_4, has two acidic hydrogen atoms.
- Some acids, such as phosphoric acid, H_3PO_4, are **triprotic acids**.

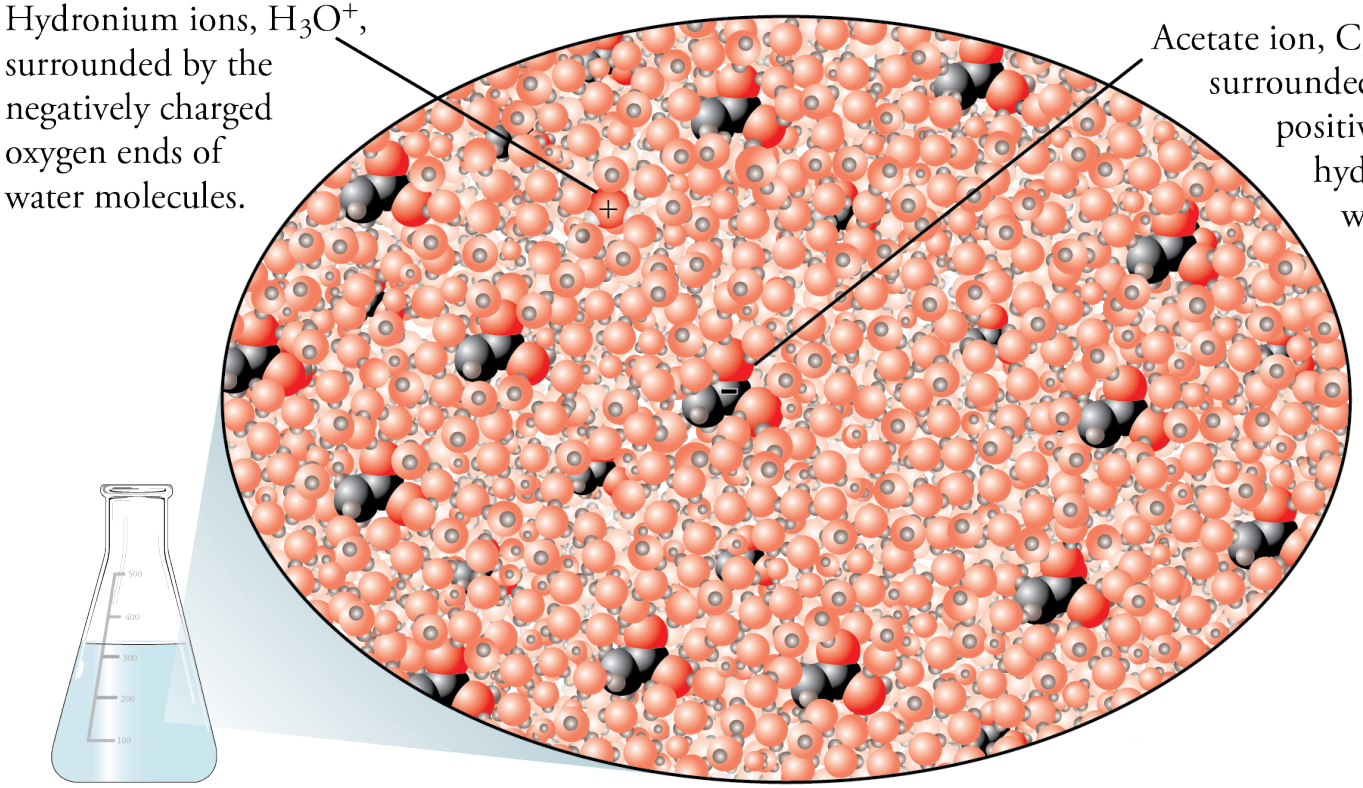
Weak Acid and Water

Acetic acid reacts with water in a reversible reaction, which forms hydronium and acetate ions.



Solution of Weak Acid

In a typical acetic acid solution, there are about 250 times as many uncharged acetic acid molecules, $HC_2H_3O_2$, as acetate ions, $C_2H_3O_2^-$.



Strong and Weak Acids

- ***Weak Acid*** = due to a reversible reaction with water, generates significantly less than one H_3O^+ for each molecule of acid added to water.
- ***Strong Acid*** = due to a completion reaction with water, generates close to one H_3O^+ for each acid molecule added to water.

Strong and Weak Acids

For every 250 molecules of the weak acid acetic acid, $HC_2H_3O_2$, added to water, there are about

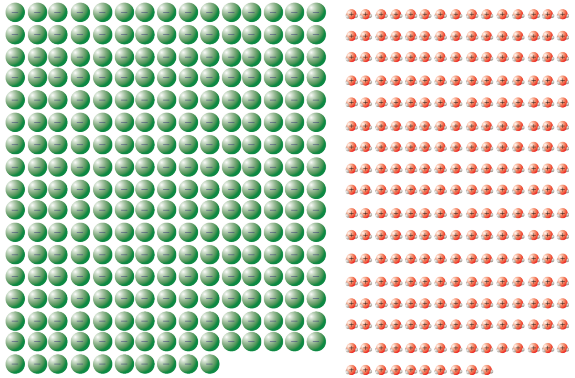
$$HC_2H_3O_2(aq) + H_2O(l) \rightleftharpoons C_2H_3O_2^-(aq) + H_3O^+(aq)$$

249 uncharged acetic acid molecules — One acetate ion — One hydronium ion

For every 250 molecules of the strong acid hydrochloric acid, HCl, added to water, there are about

$$HCl(g) + H_2O(l) \rightarrow Cl^-(aq) + H_3O^+(aq)$$

Zero uncharged HCl molecules — 250 chloride ions — 250 hydronium ions



Acid Animation and Tutorial

- There is an animation on the textbook's website that will give you a better understanding of weak and strong acids.

https://preparatorychemistry.com/acids_Canvas.html

Sulfuric Acid

$$H_2SO_4(aq) + H_2O(l) \rightarrow H_3O^+(aq) + HSO_4^-(aq)$$

$$HSO_4^-(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + SO_4^{2-}(aq)$$

Acid Summary

	Strong	**Weak**
Binary acid	hydrochloric acid, HCl(aq)	Hydrofluoric acid
Oxyacid	nitric acid, HNO_3 sulfuric acid, H_2SO_4	other acids with $H_aX_bO_c$
Organic acid	none	acetic acid, $HC_2H_3O_2$

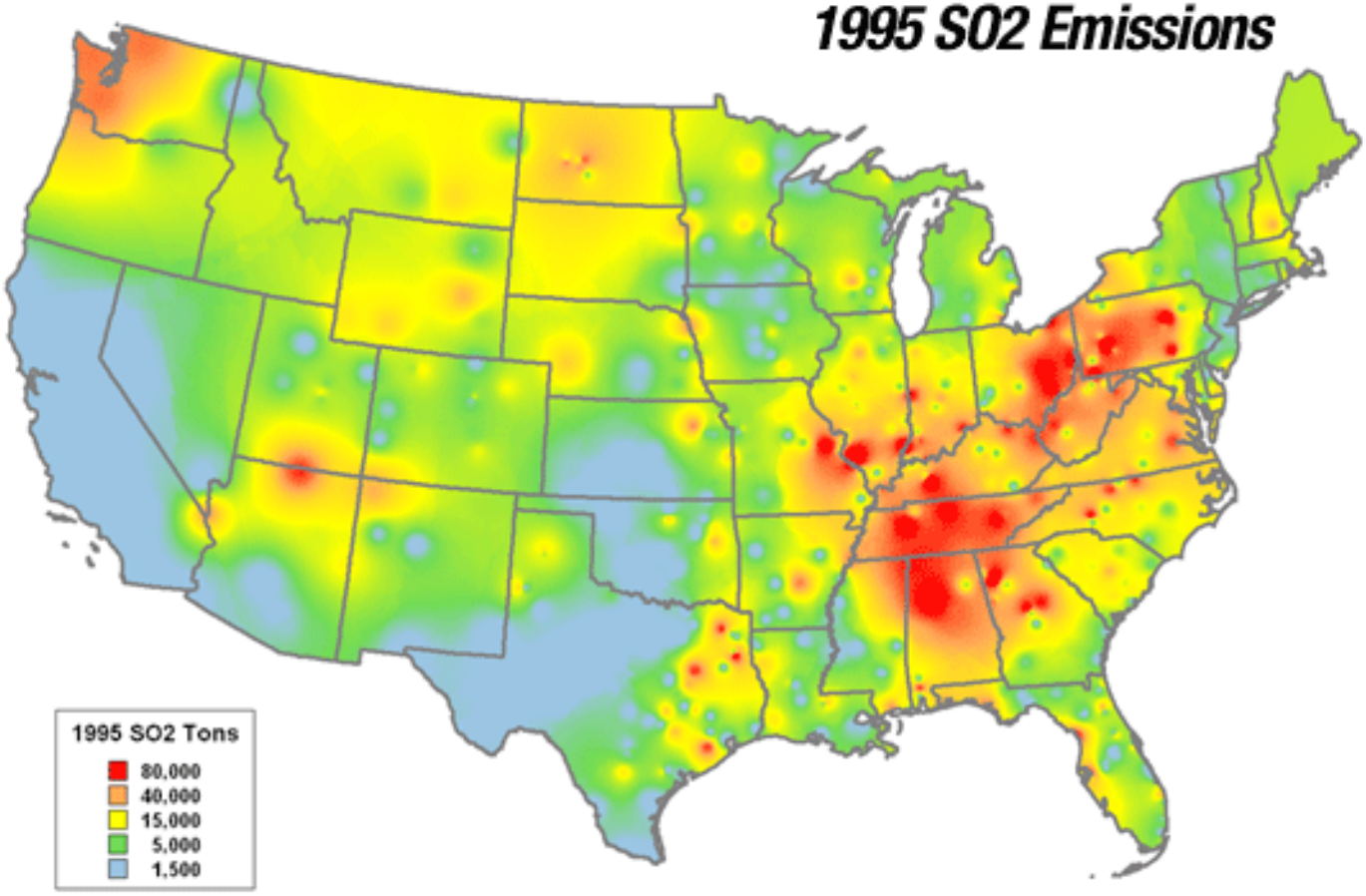
Acid Rain

- Large quantities of sulfur dioxide, SO_2, are formed and released into the air from burning sulfur-containing substances in coal in power plants and in metal ores in smelting, which involves heating of metal ores to extract metals.
- SO_2 forms sulfuric acid, H_2SO_4, in the atmosphere, which can dissolve in the clouds and form acid rain.
- Sulfuric acid forms hydronium ions.

$$H_2SO_4 + H_2O \rightarrow H_3O^+ + HSO_4^-$$

$$HSO_4^- + H_2O \rightleftharpoons H_3O^+ + SO_4^{2-}$$

1995 SO2 Emissions



NO_x and Nitric Acid

- The combination of air at high temperature, perhaps with a metal to act as a catalyst, leads to the formation of nitrogen monoxide, NO, and nitrogen dioxide, NO_2, often summarized as "NOx".
- Transportation and industry are major sources of nitrogen oxides.
- The NO_2 forms nitric acid in the atmosphere, which is a strong acid.

$$HNO_3 + H_2O \rightarrow H_3O^+ + NO_3^-$$

Acids and Acid Precursors

- Sulfur dioxide (SO_2) → sulfuric acid (H_2SO_4)
  - primarily from coal burning and smelting
- Nitrogen oxides (NO, NO_2) → nitric acid (HNO_3)
  - primarily from high-temperature combustion

strong acids

- Formic and acetic acids (HCO_2H, CH_3CO_2H)
  - primarily from biomass burning, mostly in Africa and South America
- Carbonic acid (CO_2 → H_2CO_3)
  - from CO_2 in atmosphere, responsible for acidity of pristine precipitation

weak acids

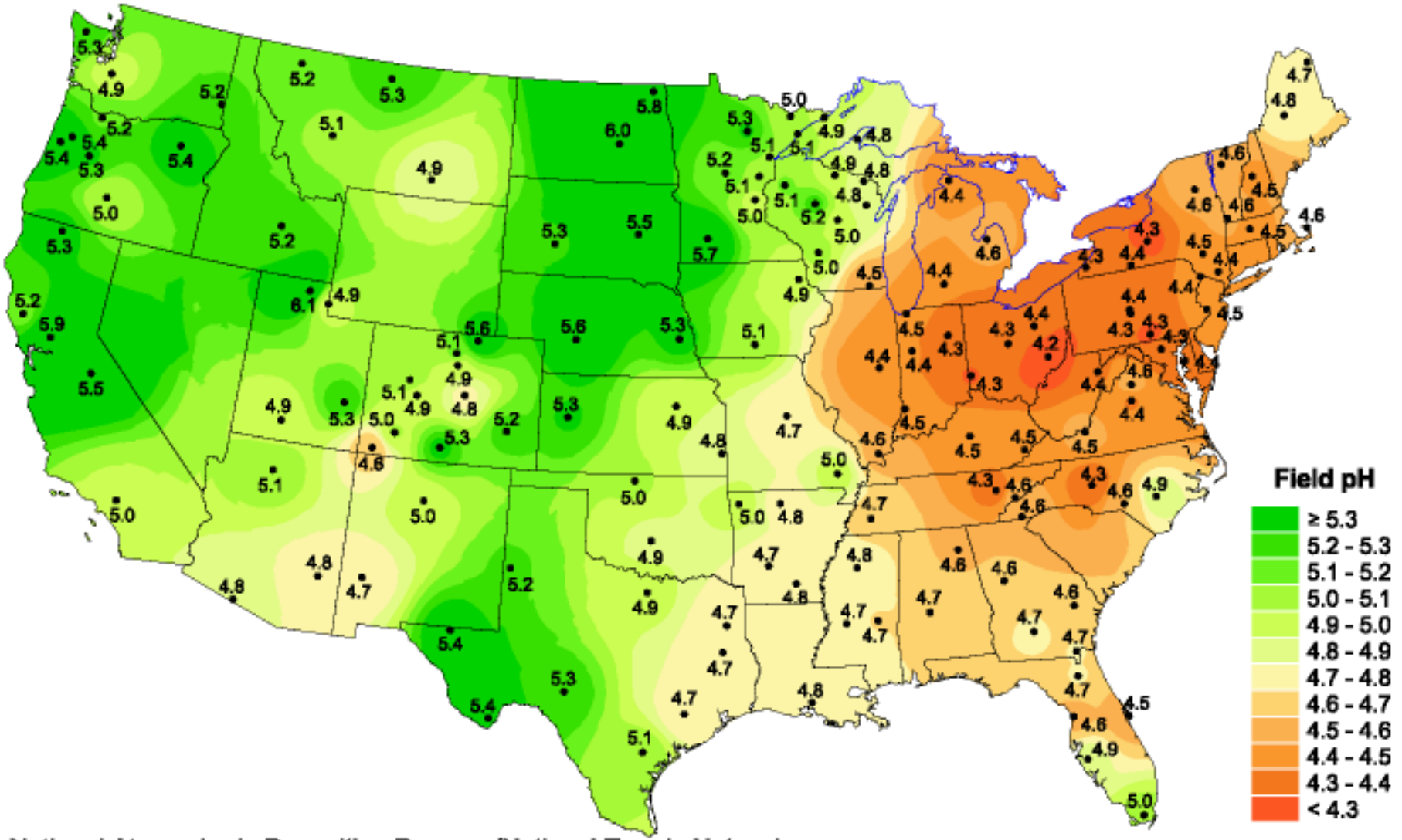
pH

- The pH scale can be used to describe the acidity and basicity of dilute solutions of acid and base.
- Acidic solutions have pHs from 0 to 7.
- The lower the pH, the more acidic the solution, and a decrease in one pH unit is associated with an increase of 10-times the hydronium ion concentration.
- Therefore, small changes in pH reflect significant changes in H_3O^+ concentration.

Pristine Rain and Acid Rain

- Due to acids dissolved in natural rain, such as the carbonic acid that forms when CO_2 dissolves in water, pristine or unpolluted rain has a pH of about 5.6.
- Acid rain can have a pH close to 4.

Rain pH 1999



National Atmospheric Deposition Program/National Trends Network
http://nadp.sws.uiuc.edu

Impacts

- Lowering pH can damage freshwater ecosystems, forests, agriculture, human health, buildings, and other property.

Damage to Human Health

- More acidic rain dissolves more toxic metals in the soil, which increases the level of these metals in water systems, leading to consumption of fish with elevated concentrations of toxic metals (Al, Pb, Cd, Hg, Cu, Zn).
- Corrosion of pipes results in excess levels of Cu, Zn, Pb in drinking water.

Damage to Buildings and Property

- Acids etch glass, damage roofing and other building materials, and damage plastics and paint (especially automotive paint).
- Carbonate stones (marble, limestone, etc.), cement, mortar are dissolved by acids:

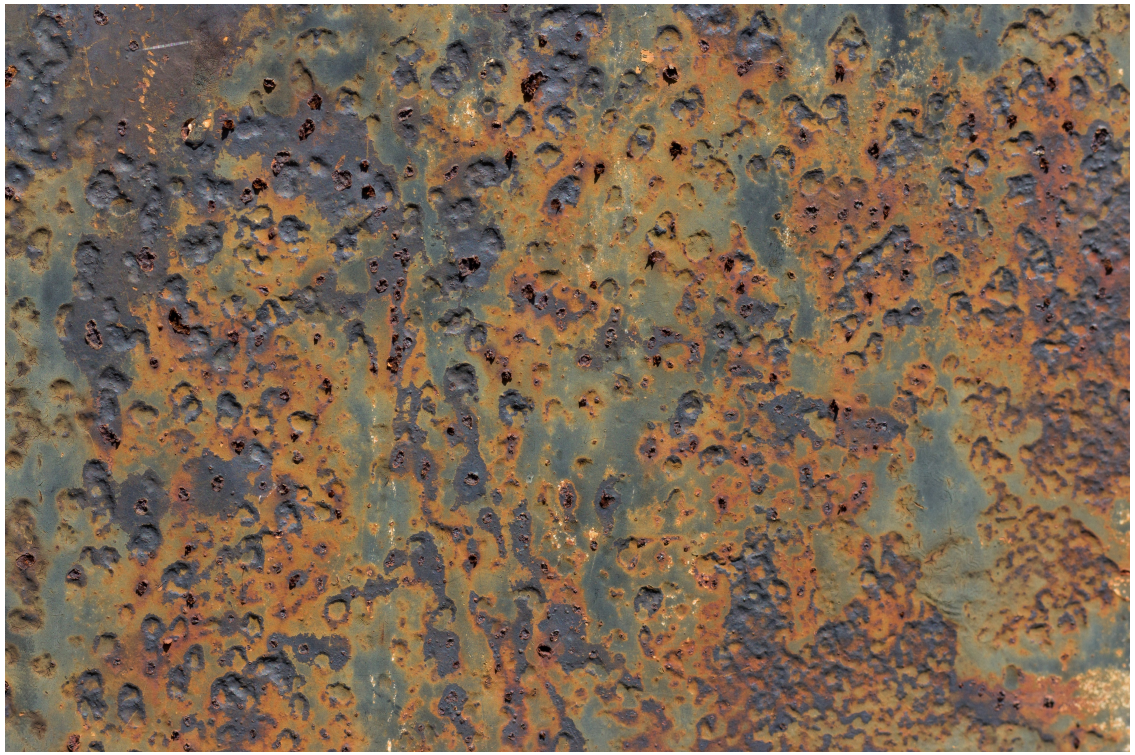
$$CaCO_3(s) + 2H_3O^+(aq) \rightarrow Ca^{2+}(aq) + CO_2(g) + 3H_2O(l)$$

Damage to Art

The statues on the left were transported by William Randolph Hearst to his home in San Simeon, California. Because it so rarely rains there, and because San Simeon is far from any major sources of pollution, these statues are in much better condition than the similar statues found elsewhere, such as the one on the right, that have been damaged by acid rain.

Effects on Metals

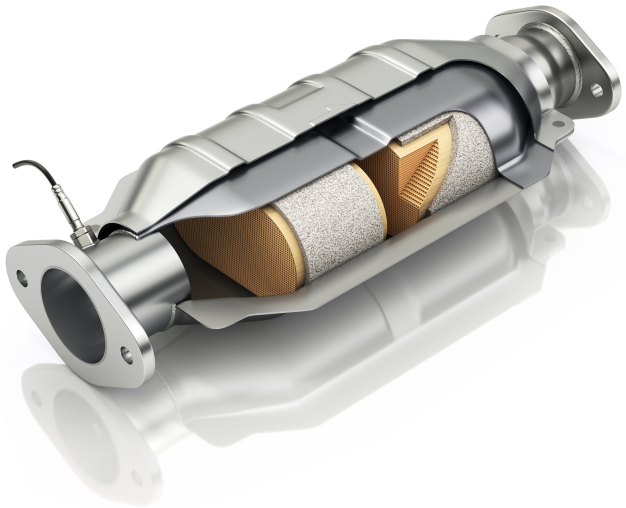
- Acid rain speeds the corrosion of metals.



Automobile Catalytic Converters

- Catalytic converters can convert up to 95% of the NO and NO_2 back to nitrogen and oxygen.

$$2NO \rightarrow N_2 + O_2 \qquad 2NO_2 \rightarrow N_2 + 2O_2$$



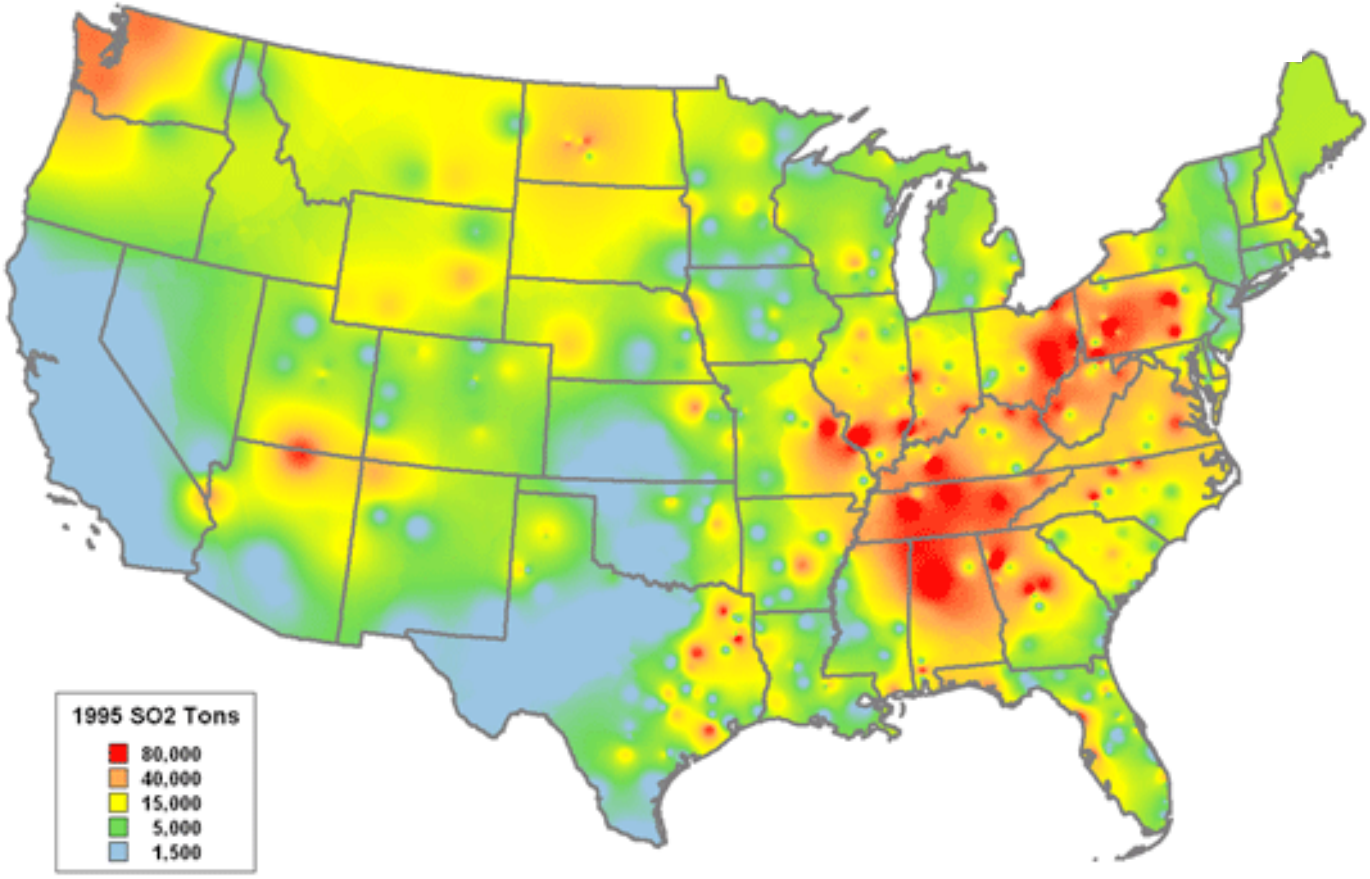
Mitigation - Sulfur

- Switch from coal to natural gas (0.001% S)
- Switch to low-sulfur coal
- Power plant scrubbers can use CaO (lime), $CaCO_3$ (limestone), or $Ca(OH)_2$ (lime) to remove SO_2 from the stack gases.

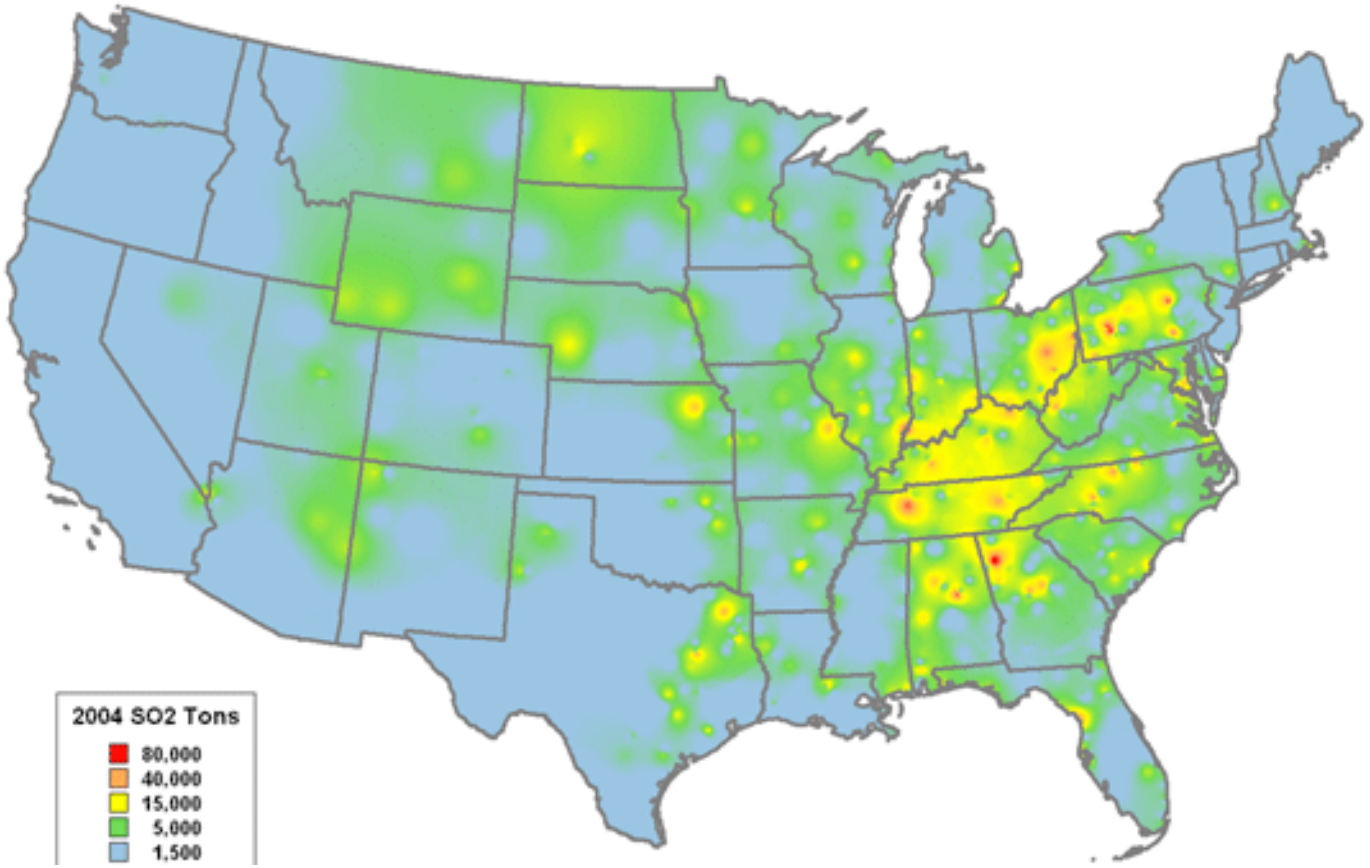
SO_2 Emissions Reduction

- Due largely to the US EPA's Acid Rain Program, the U.S. had a 33% decrease in SO_2 emissions between 1983 and 2002.

1995 SO_2 Emissions



2004 SO_2 Emissions



Two Types of Acids

- Binary acids, such as hydrochloric acid, HCl(*aq*).
- Oxyacids, such as sulfuric acid, H_2SO_4, and nitric acid, HNO_3.

Names and Formulas of Binary Acids

- Names have the general form of *hydro(root)ic acid*, such as hydrochloric acid.
- The formulas are usually followed by (*aq*), such as HCl(*aq*).

Binary Acids

Formula	**Named as Binary Covalent Compound**	**Acid Formula**	**Named as Binary acid**
HF or HF(*g*)	hydrogen monofluoride or hydrogen fluoride	HF(*aq*)	hydrofluoric acid
HCl or HCl(*g*)	hydrogen monochloride or hydrogen chloride	HCl(*aq*)	hydrochloric acid
HBr or HBr(*g*)	hydrogen monobromide or hydrogen bromide	HBr(*aq*)	hydrobromic acid
HI or HI(*g*)	hydrogen moniodide or hydrogen iodide	HI(*aq*)	hydriodic acid

Names and Formulas for Oxyacids

- If enough H^+ ions are added to a (root)ate polyatomic ion to completely neutralize its charge, the (root)ic acid is formed.
  - Nitrate, NO_3^-, goes to nitric acid, HNO_3.
  - Sulfate, SO_4^{2-}, goes to sulfuric acid, H_2SO_4. (Note the -ur- in the name.)
  - Phosphate, PO_4^{3-}, goes to phosphoric acid, H_3PO_4. (Note the -or- in the name.)

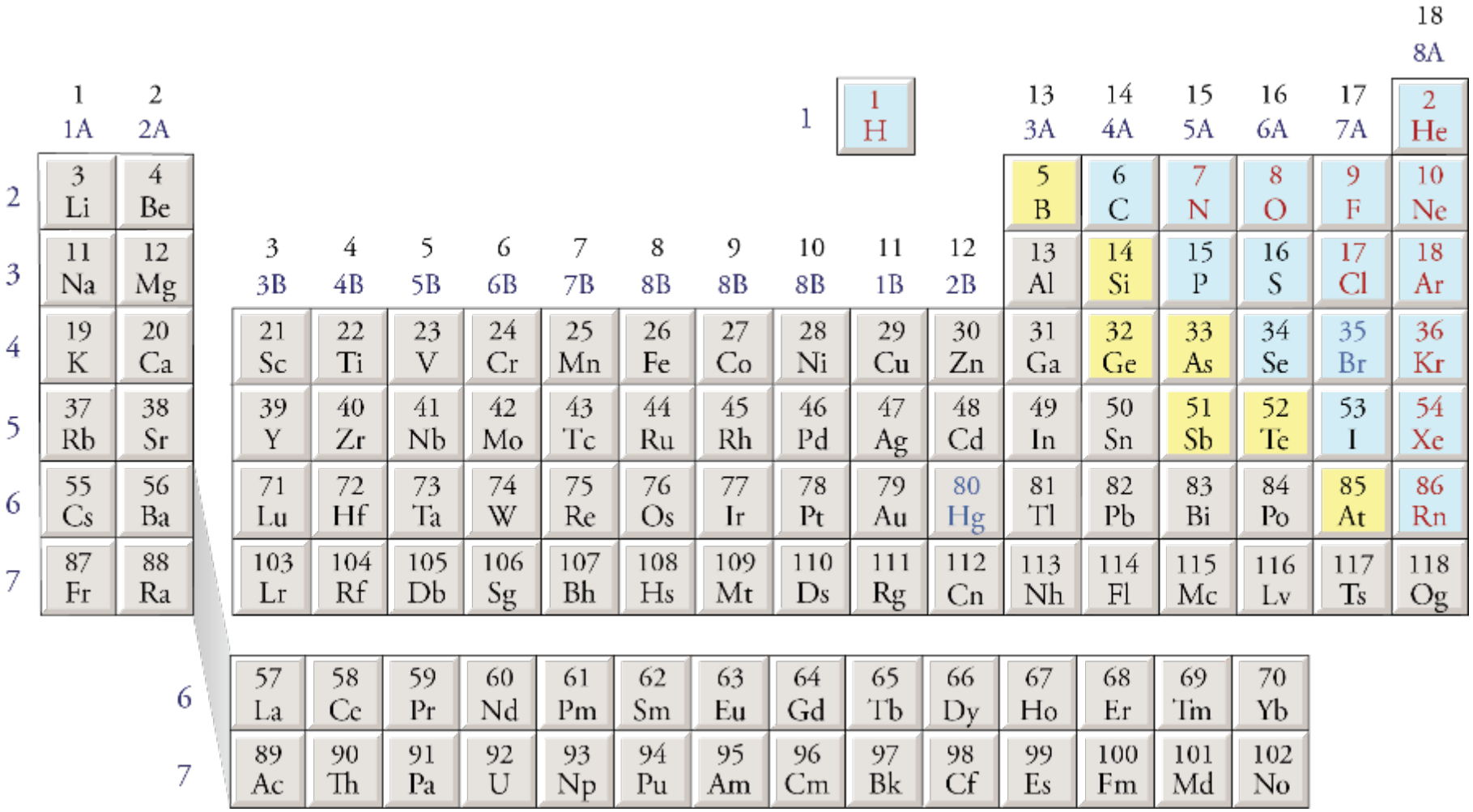
Oxyacids

Oxyanion Formula	**Oxyanion Name**	**Oxyacid Formula**	**Oxyacid Name**
NO_3^-	nitrate	HNO_3	nitric acid
$C_2H_3O_2^-$	acetate	$HC_2H_3O_2$	acetic acid
SO_4^{2-}	sulfate	H_2SO4_4	sulfuric acid (Note that the whole name *sulfur* is used in the oxyacid name.)
CO_3^{2-}	carbonate	H_2CO_3	carbonic acid
PO_4^{3-}	phosphate	H_3PO_4	phosphoric acid (Note that the root of phosphorus in an oxyacid name is *phosphor*-.)

Memorized Names

Name	**Formula**	**Name**	**Formula**
water	H_2O	ammonia	NH_3
methane	CH_4	ethane	C_2H_6
propane	C_3H_8	methanol (methyl alcohol)	CH_3OH
ethanol (ethyl alcohol)	C_2H_5OH	2-propanol (isopropyl alcohol)	C_3H_7OH

Periodic Table



https://preparatorychemistry.com/Bishop_periodic_table.pdf

Chemical Nomenclature

- General procedure for naming compounds
  - **Step 1:** Decide what type of compound the name or formula represents.
  - **Step 2:** Apply the rules for writing the name or formula for that type of compound.

Table 6.13 (atoms) or 5.5 (chemistry)

Type of Compound	General Formula	Examples	General Name	Examples
Binary covalent	A_aB_b	N_2O_5 or CO_2	(prefix unless mono)(name of first element in formula) (prefix)(root of second element)ide	dinitrogen pentoxide or carbon dioxide
Binary ionic	M_aA_b	NaCl or $FeCl_3$	(name of metal) (root of nonmetal)ide **or** (name of metal)(Roman numeral) (root of nonmetal)ide	sodium chloride or iron(III) chloride
Ionic with polyatomic ion(s)	M_aX_b or $(NH_4)_aX_b$ X = formula of polyatomic ion	Li_2HPO_4 or $CuSO_4$ or NH_4Cl or $(NH_4)_2SO_4$	(name of metal) (name of polyatomic ion) **or** (name of metal)(Roman numeral) (name of polyatomic ion) **or** ammonium (root of nonmetal)ide **or** ammonium (name of polyatomic ion)	lithium hydrogen phosphate or copper(II) sulfate or ammonium chloride or ammonium sulfate
Binary acid	HX(*aq*)	HCl(*aq*)	hydro(root)ic acid	hydrochloric acid
Oxyacid	$H_aX_bO_c$	HNO_3 or H_2SO_4 or H_3PO_4	(root)ic acid	nitric acid or sulfuric acid or phosphoric acid

Practice

- The web address below will take you to tool that will help you recognize different types of substances.

https://preparatorychemistry.com/Type_substance_Canvas.html

Nomenclature Summary

Type of Compound	General Formula	Examples	General Name	Examples
Binary covalent	A_aB_b	N_2O_5 or CO_2	(prefix unless mono)(name of first element in formula) (prefix)(root of second element)ide	dinitrogen pentoxide or carbon dioxide
Binary ionic	M_aA_b AlF_3	NaCl or $FeCl_3$	(name of metal) (root of nonmetal)ide **or** (name of metal)(Roman numeral) (root of nonmetal)ide	sodium chloride or iron(III) chloride
Ionic with polyatomic ion(s)	M_aX_b or $(NH_4)_aX_b$ X = formula of polyatomic ion	Li_2HPO_4 or $CuSO_4$ or NH_4Cl or $(NH_4)_2SO_4$	(name of metal) (name of polyatomic ion) **or** (name of metal)(Roman numeral) (name of polyatomic ion) **or** ammonium (root of nonmetal)ide **or** ammonium (name of polyatomic ion)	lithium hydrogen phosphate or copper(II) sulfate or ammonium chloride or ammonium sulfate
Binary acid	HX(*aq*)	HCl(*aq*)	hydro(root)ic acid	hydrochloric acid
Oxyacid	$H_aX_bO_c$	HNO_3 or H_2SO_4 or H_3PO_4	(root)ic acid	nitric acid or sulfuric acid or phosphoric acid

AlF_3

- Metal-nonmetal (M_aA_b) so binary ionic
- Al only one charge – just name of metal with no Roman numeral.
  - Metals without Roman numerals –Groups 1, 2, 3, and Al, Zn, Cd, and Ag
- The cation name is aluminum.
- Monatomic anion names – (root)ide
- Name of the anion is fluoride.
- **Aluminum fluoride**

Nomenclature Summary

Type of Compound	General Formula	Examples	General Name	Examples
Binary covalent	A_aB_b PF_3	N_2O_5 or CO_2	(prefix unless mono)(name of first element in formula) (prefix)(root of second element)ide	dinitrogen pentoxide or carbon dioxide
Binary ionic	M_aA_b	NaCl or $FeCl_3$	(name of metal) (root of nonmetal)ide **or** (name of metal)(Roman numeral) (root of nonmetal)ide	sodium chloride or iron(III) chloride
Ionic with polyatomic ion(s)	M_aX_b or $(NH_4)_aX_b$ X = formula of polyatomic ion	Li_2HPO_4 or $CuSO_4$ or NH_4Cl or $(NH_4)_2SO_4$	(name of metal) (name of polyatomic ion) **or** (name of metal)(Roman numeral) (name of polyatomic ion) **or** ammonium (root of nonmetal)ide **or** ammonium (name of polyatomic ion)	lithium hydrogen phosphate or copper(II) sulfate or ammonium chloride or ammonium sulfate
Binary acid	HX(*aq*)	HCl(*aq*)	hydro(root)ic acid	hydrochloric acid
Oxyacid	$H_aX_bO_c$	HNO_3 or H_2SO_4 or H_3PO_4	(root)ic acid	nitric acid or sulfuric acid or phosphoric acid

PF_3

- Nonmetal-nonmetal (A_aB_b) so binary covalent.
- (prefix unless mono)(name of first element in formula) (prefix)(root of second element)ide
- Leave off mono on first part of name.
- We use the prefix tri- to show three fluorine atoms.
- The root of the name fluorine is fluor-
- **Phosphorus trifluoride**

Nomenclature Summary

Type of Compound	General Formula	Examples	General Name	Examples
Binary covalent	A_aB_b	N_2O_5 or CO_2	(prefix unless mono)(name of first element in formula) (prefix)(root of second element)ide	dinitrogen pentoxide or carbon dioxide
Binary ionic	M_aA_b	NaCl or $FeCl_3$	(name of metal) (root of nonmetal)ide **or** (name of metal)(Roman numeral) (root of nonmetal)ide	sodium chloride or iron(III) chloride
Ionic with polyatomic ion(s)	M_aX_b or $(NH_4)_aX_b$ X = formula of polyatomic ion	Li_2HPO_4 or $CuSO_4$ or NH_4Cl or $(NH_4)_2SO_4$	(name of metal) (name of polyatomic ion) **or** (name of metal)(Roman numeral) (name of polyatomic ion) **or** ammonium (root of nonmetal)ide **or** ammonium (name of polyatomic ion)	lithium hydrogen phosphate or copper(II) sulfate or ammonium chloride or ammonium sulfate
Binary acid	HX(*aq*)	HCl(*aq*)	hydro(root)ic acid	hydrochloric acid
Oxyacid	$H_aX_bO_c$ H_3PO_4	HNO_3 or H_2SO_4 or H_3PO_4	(root)ic acid	nitric acid or sulfuric acid or phosphoric acid

H_3PO_4

- Form of oxyacid, $H_aX_bO_c$
- (root)ic acid
- Use “phosphor” as the root in acid names.
- H_3PO_4 is **phosphoric acid.**

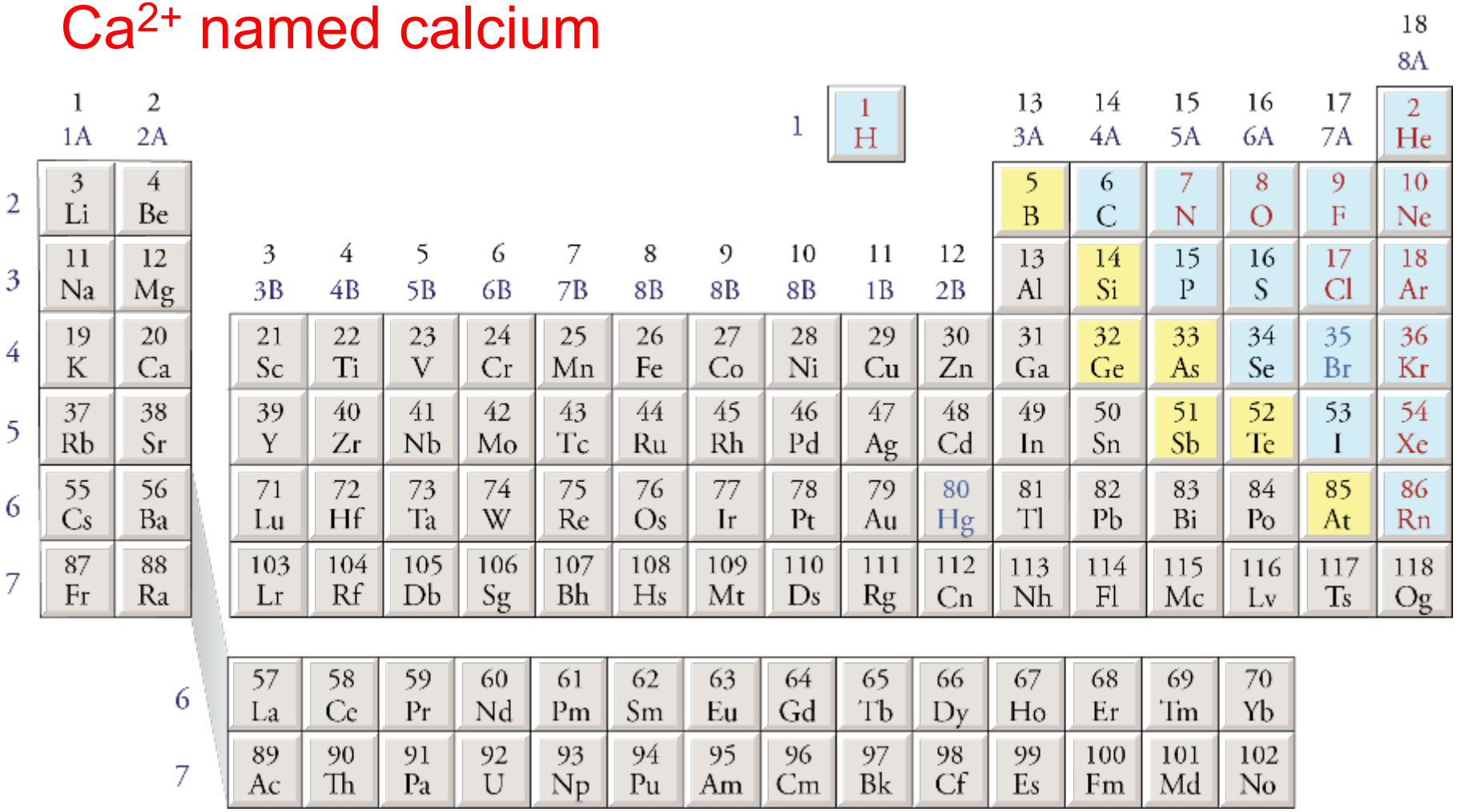
Nomenclature Summary

Type of Compound	General Formula	Examples	General Name	Examples
Binary covalent	A_aB_b	N_2O_5 or CO_2	(prefix unless mono)(name of first element in formula) (prefix)(root of second element)ide	dinitrogen pentoxide or carbon dioxide
Binary ionic	M_aA_b	NaCl or $FeCl_3$	(name of metal) (root of nonmetal)ide **or** (name of metal)(Roman numeral) (root of nonmetal)ide	sodium chloride or iron(III) chloride
Ionic with polyatomic ion(s)	M_aX_b or $(NH_4)_aX_b$ X = formula of polyatomic ion $CaCO_3$	Li_2HPO_4 or $CuSO_4$ or NH_4Cl or $(NH_4)_2SO_4$	(name of metal) (name of polyatomic ion) **or** (name of metal)(Roman numeral) (name of polyatomic ion) **or** ammonium (root of nonmetal)ide **or** ammonium (name of polyatomic ion)	lithium hydrogen phosphate or copper(II) sulfate or ammonium chloride or ammonium sulfate
Binary acid	HX(*aq*)	HCl(*aq*)	hydro(root)ic acid	hydrochloric acid
Oxyacid	$H_aX_bO_c$	HNO_3 or H_2SO_4 or H_3PO_4	(root)ic acid	nitric acid or sulfuric acid or phosphoric acid

$CaCO_3$

Periodic Table

Ca^{2+} named calcium



$CaCO_3$

Ion	Name	Ion	Name
NH_4^+	ammonium	NO_3^-	nitrate
OH^-	hydroxide	SO_4^{2-}	sulfate
CO_3^{2-}	carbonate	$C_2H_3O_2^-$	acetate
PO_4^{3-}	phosphate		

$CaCO_3$

- Metal polyatomic ion (M_aX_b) with X representing a polyatomic ion
- Ca is in Group 2, so the cation name is just the name of the metal.
- Need to memorize polyatomic names and formulas.
- $CaCO_3$ is **calcium carbonate.**

Nomenclature Summary

Type of Compound	General Formula	Examples	General Name	Examples
Binary covalent	A_aB_b	N_2O_5 or CO_2	(prefix unless mono)(name of first element in formula) (prefix)(root of second element)ide	dinitrogen pentoxide or carbon dioxide
Binary ionic	M_aA_b	NaCl or $FeCl_3$	(name of metal) (root of nonmetal)ide **or** (name of metal)(Roman numeral) (root of nonmetal)ide	sodium chloride or iron(III) chloride
Ionic with polyatomic ion(s)	M_aX_b or $(NH_4)_aX_b$ X = formula of polyatomic ion $Ca(HSO_4)_2$	Li_2HPO_4 or $CuSO_4$ or NH_4Cl or $(NH_4)_2SO_4$	(name of metal) (name of polyatomic ion) **or** (name of metal)(Roman numeral) (name of polyatomic ion) **or** ammonium (root of nonmetal)ide **or** ammonium (name of polyatomic ion)	lithium hydrogen phosphate or copper(II) sulfate or ammonium chloride or ammonium sulfate
Binary acid	HX(*aq*)	HCl(*aq*)	hydro(root)ic acid	hydrochloric acid
Oxyacid	$H_aX_bO_c$	HNO_3 or H_2SO_4 or H_3PO_4	(root)ic acid	nitric acid or sulfuric acid or phosphoric acid

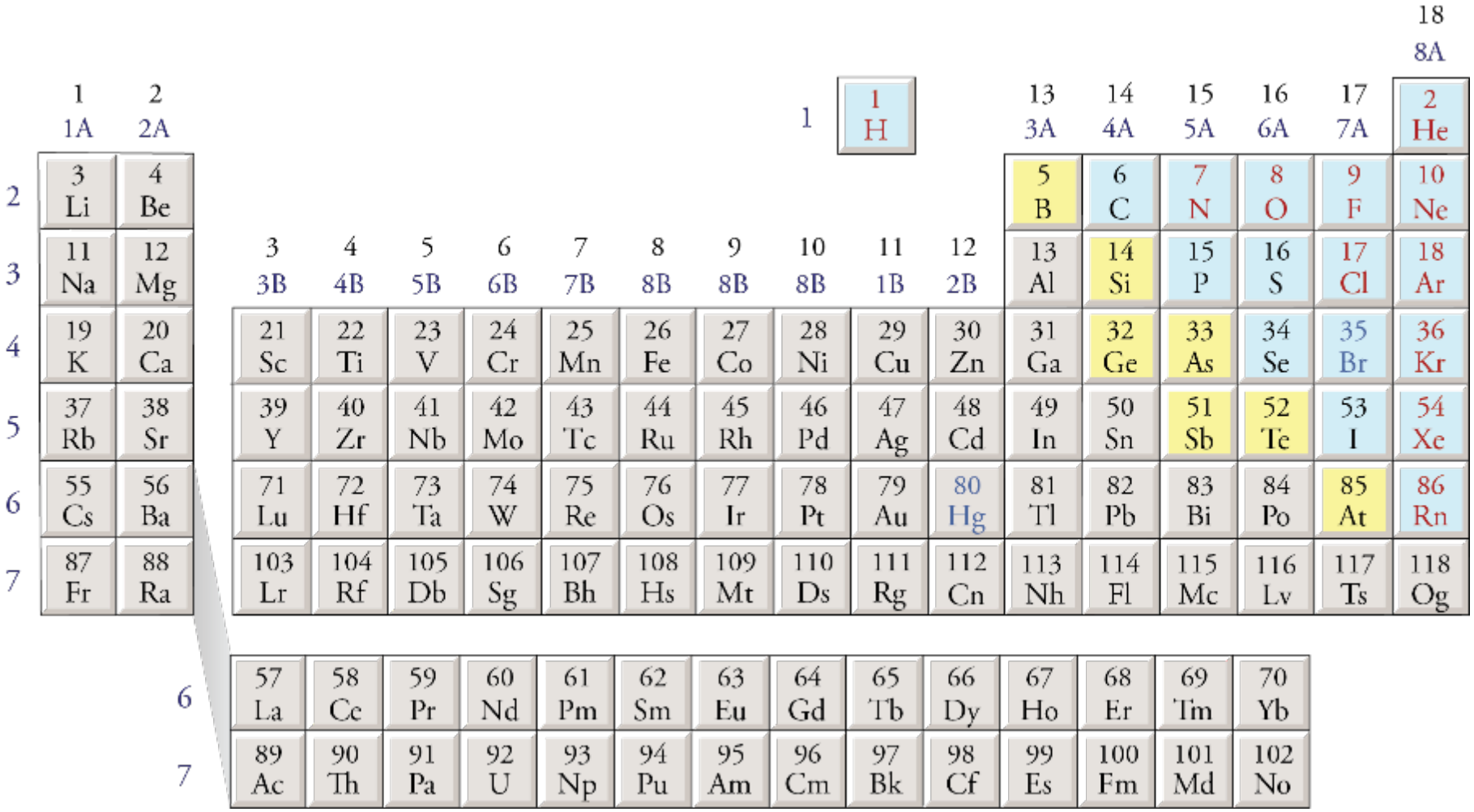
$Ca(HSO_4)_2$

- The name for the cation is calcium.
- Memorize SO_4^{2-} as sulfate.
- When a polyatomic anion with a charge of -2 has an H^+ added, we add “hydrogen” to the name of the anion.
- $Ca(HSO_4)_2$ is **calcium hydrogen sulfate.**

Nomenclature Summary

Type of Compound	General Formula	Examples	General Name	Examples
Binary covalent	A_aB_b	N_2O_5 or CO_2	(prefix unless mono)(name of first element in formula) (prefix)(root of second element)ide	dinitrogen pentoxide or carbon dioxide
Binary ionic	M_aA_b $CuCl_2$	NaCl or $FeCl_3$	(name of metal) (root of nonmetal)ide **or** (name of metal)(Roman numeral) (root of nonmetal)ide	sodium chloride or iron(III) chloride
Ionic with polyatomic ion(s)	M_aX_b or $(NH_4)_aX_b$ X = formula of polyatomic ion	Li_2HPO_4 or $CuSO_4$ or NH_4Cl or $(NH_4)_2SO_4$	(name of metal) (name of polyatomic ion) **or** (name of metal)(Roman numeral) (name of polyatomic ion) **or** ammonium (root of nonmetal)ide **or** ammonium (name of polyatomic ion)	lithium hydrogen phosphate or copper(II) sulfate or ammonium chloride or ammonium sulfate
Binary acid	HX(*aq*)	HCl(*aq*)	hydro(root)ic acid	hydrochloric acid
Oxyacid	$H_aX_bO_c$	HNO_3 or H_2SO_4 or H_3PO_4	(root)ic acid	nitric acid or sulfuric acid or phosphoric acid

Periodic Table



$CuCl_2$

- Metal-nonmetal (M_aA_b) so binary ionic
- Cu is not on the list of metals without a Roman numeral, so we need a Roman numeral to show the charge.
- Cl is in group 17, so it is -1.
- Two Cl^- ions would be -2.
- Cu must be +2 to balance the charge, so the name of the cation is copper(II).
- Monatomic anions are named (root)ide, so Cl^- is chloride.
- $CuCl_2$ is **copper(II) chloride.**

Nomenclature Summary

Type of Compound	General Formula	Examples	General Name	Examples
Binary covalent	A_aB_b	N_2O_5 or CO_2	(prefix unless mono)(name of first element in formula) (prefix)(root of second element)ide	dinitrogen pentoxide or carbon dioxide
Binary ionic	M_aA_b	NaCl or $FeCl_3$	(name of metal) (root of nonmetal)ide **or** (name of metal)(Roman numeral) (root of nonmetal)ide	sodium chloride or iron(III) chloride
Ionic with polyatomic ion(s)	M_aX_b or $(NH_4)_aX_b$ X = formula of polyatomic ion NH_4F	Li_2HPO_4 or $CuSO_4$ or NH_4Cl or $(NH_4)_2SO_4$	(name of metal) (name of polyatomic ion) **or** (name of metal)(Roman numeral) (name of polyatomic ion) **or** ammonium (root of nonmetal)ide **or** ammonium (name of polyatomic ion)	lithium hydrogen phosphate or copper(II) sulfate or ammonium chloride or ammonium sulfate
Binary acid	HX(*aq*)	HCl(*aq*)	hydro(root)ic acid	hydrochloric acid
Oxyacid	$H_aX_bO_c$	HNO_3 or H_2SO_4 or H_3PO_4	(root)ic acid	nitric acid or sulfuric acid or phosphoric acid

NH_4F

- Polyatomic ion-nonmetal so ionic with a polyatomic ion.
- Memorize NH_4^+ as ammonium.
- Monatomic anions are named (root)ide.
- NH_4F is **ammonium fluoride.**

Nomenclature Summary

Type of Compound	General Formula	Examples	General Name	Examples
Binary covalent	A_aB_b	N_2O_5 or CO_2	(prefix unless mono)(name of first element in formula) (prefix)(root of second element)ide	dinitrogen pentoxide or carbon dioxide
Binary ionic	M_aA_b	NaCl or $FeCl_3$	(name of metal) (root of nonmetal)ide **or** (name of metal)(Roman numeral) (root of nonmetal)ide	sodium chloride or iron(III) chloride
Ionic with polyatomic ion(s)	M_aX_b or $(NH_4)_aX_b$ X = formula of polyatomic ion HCl(*aq*)	Li_2HPO_4 or $CuSO_4$ or NH_4Cl or $(NH_4)_2SO_4$	(name of metal) (name of polyatomic ion) **or** (name of metal)(Roman numeral) (name of polyatomic ion) **or** ammonium (root of nonmetal)ide **or** ammonium (name of polyatomic ion)	lithium hydrogen phosphate or copper(II) sulfate or ammonium chloride or ammonium sulfate
Binary acid	HX(*aq*)	HCl(*aq*)	hydro(root)ic acid	hydrochloric acid
Oxyacid	$H_aX_bO_c$	HNO_3 or H_2SO_4 or H_3PO_4	(root)ic acid	nitric acid or sulfuric acid or phosphoric acid

HCl(*aq*)

- HX(aq) is the form of a binary acid.
- Named hydro(root)ic acid
- HCl(*aq*) is **hydrochloric acid.**

Nomenclature Summary

Type of Compound	General Formula	Examples	General Name	Examples
Binary covalent	A_aB_b	N_2O_5 or CO_2	(prefix unless mono)(name of first element in formula) (prefix)(root of second element)ide	dinitrogen pentoxide or carbon dioxide
Binary ionic	M_aA_b	NaCl or $FeCl_3$	(name of metal) (root of nonmetal)ide **or** (name of metal)(Roman numeral) (root of nonmetal)ide	sodium chloride or iron(III) chloride
Ionic with polyatomic ion(s) $(NH_4)_3PO_4$	M_aX_b or $(NH_4)_aX_b$ X = formula of polyatomic ion	Li_2HPO_4 or $CuSO_4$ or NH_4Cl or $(NH_4)_2SO_4$	(name of metal) (name of polyatomic ion) **or** (name of metal)(Roman numeral) (name of polyatomic ion) **or** ammonium (root of nonmetal)ide **or** ammonium (name of polyatomic ion)	lithium hydrogen phosphate or copper(II) sulfate or ammonium chloride or ammonium sulfate
Binary acid	HX(*aq*)	HCl(*aq*)	hydro(root)ic acid	hydrochloric acid
Oxyacid	$H_aX_bO_c$	HNO_3 or H_2SO_4 or H_3PO_4	(root)ic acid	nitric acid or sulfuric acid or phosphoric acid

$(NH_4)_3PO_4$

- Two polyatomic ions so ionic with polyatomic ions.
- Need to memorize names and formulas for polyatomic ions.
- $(NH_4)_3PO_4$ is **ammonium phosphate.**

Nomenclature Summary

Type of Compound	General Formula	Examples	General Name	Examples
Binary covalent	A_aB_b	N_2O_5 or CO_2	(prefix unless mono)(name of first element in formula) (prefix)(root of second element)ide	dinitrogen pentoxide or carbon dioxide
Binary ionic	M_aA_b	NaCl or $FeCl_3$	(name of metal) (root of nonmetal)ide **or** (name of metal)(Roman numeral) (root of nonmetal)ide	sodium chloride or iron(III) chloride
Ionic with polyatomic ion(s)	M_aX_b or $(NH_4)_aX_b$ X = formula of polyatomic ion	Li_2HPO_4 or $CuSO_4$ or NH_4Cl or $(NH_4)_2SO_4$	(name of metal) (name of polyatomic ion) **or** (name of metal)(Roman numeral) (name of polyatomic ion) **or** ammonium (root of nonmetal)ide **or** ammonium (name of polyatomic ion)	lithium hydrogen phosphate or copper(II) sulfate or ammonium chloride or ammonium sulfate
Binary acid	HX(*aq*)	HCl(*aq*)	hydro(root)ic acid	hydrochloric acid
Oxyacid	$H_aX_bO_c$	HNO_3 or H_2SO_4 or H_3PO_4	(root)ic acid	nitric acid or sulfuric acid or phosphoric acid

Ammonium nitrate

Steps for Ionic Formulas

- The steps for writing formulas for ionic compounds are
  - Determine the formula, including charge, for the ions.
  - Determine the ratio of the ions necessary to balance the charge.

ammonium nitrate

- Ammonium and nitrate are both polyatomic ions.
- The memorized formula for ammonium is NH_4^+.
- The memorized formula for nitrate is NO_3^-.
- A 1:1 ratio balances the charge.
- Ammonium nitrate is **NH_4NO_3.** (Note no parentheses)

acetic acid

- It is probably best to memorize acetic acid as $HC_2H_3O_2$. It is also described at CH_3CO_2H.
- $C_2H_3O_2^-$ is acetate.
- If you add enough H^+ ions to the –ate anion to neutralize the charge, you get the –ic acid.
- Acetic acid is **$HC_2H_3O_2$**.

Nomenclature Summary

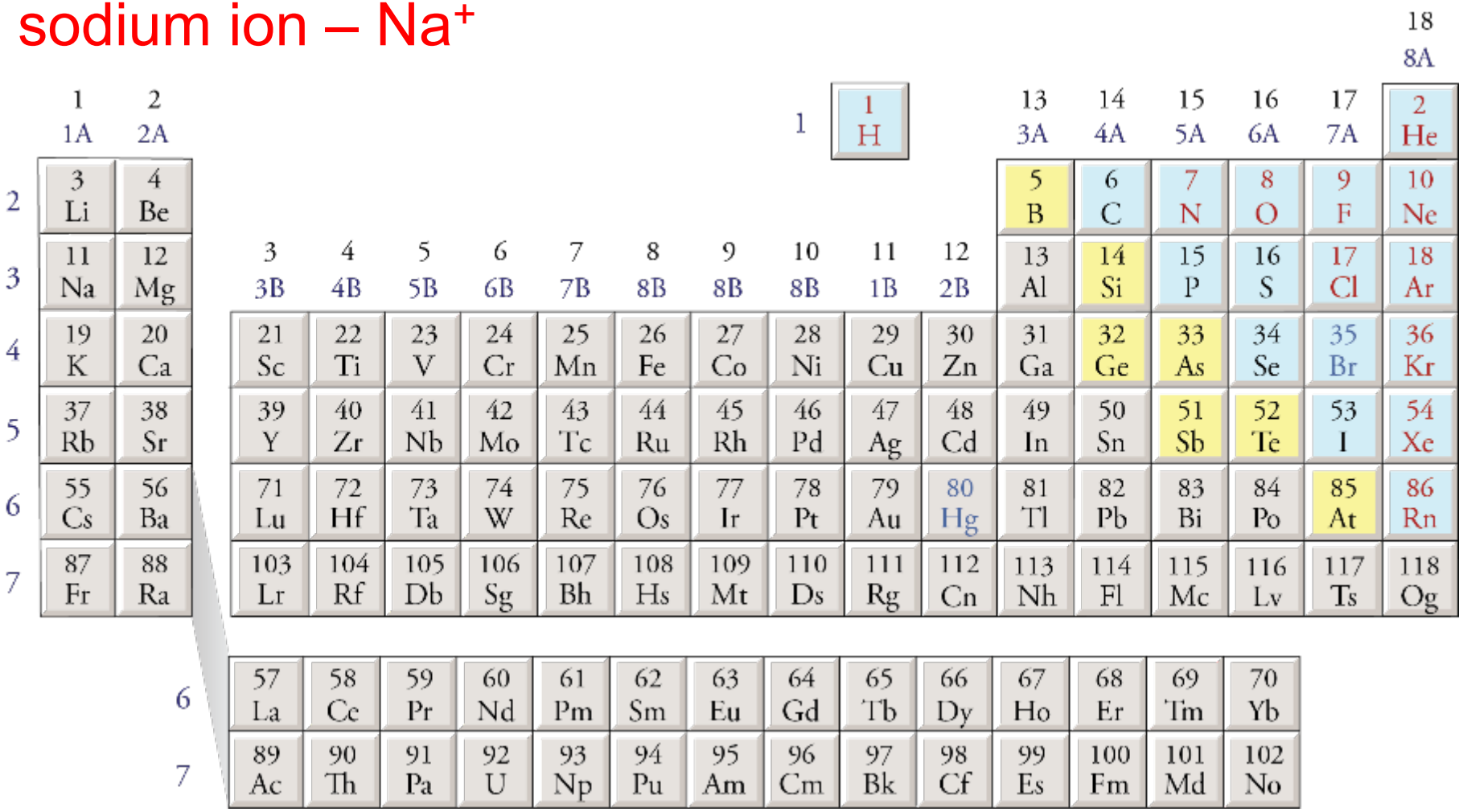
Type of Compound	General Formula	Examples	General Name	Examples
Binary covalent	A_aB_b	N_2O_5 or CO_2	(prefix unless mono)(name of first element in formula) (prefix)(root of second element)ide	dinitrogen pentoxide or carbon dioxide
Binary ionic	M_aA_b	NaCl or $FeCl_3$	(name of metal) (root of nonmetal)ide **or** (name of metal)(Roman numeral) (root of nonmetal)ide	sodium chloride or iron(III) chloride
Ionic with polyatomic ion(s)	M_aX_b or $(NH_4)_aX_b$ X = formula of polyatomic ion	Li_2HPO_4 or $CuSO_4$ or NH_4Cl or $(NH_4)_2SO_4$	(name of metal) (name of polyatomic ion) **or** (name of metal)(Roman numeral) (name of polyatomic ion) **or** ammonium (root of nonmetal)ide **or** ammonium (name of polyatomic ion)	lithium hydrogen phosphate or copper(II) sulfate or ammonium chloride or ammonium sulfate
Binary acid	HX(*aq*)	HCl(*aq*)	hydro(root)ic acid	hydrochloric acid
Oxyacid	$H_aX_bO_c$	HNO_3 or H_2SO_4 or H_3PO_4	(root)ic acid	nitric acid or sulfuric acid or phosphoric acid

sodium hydrogen sulfate

sodium hydrogen sulfate

Periodic Table

sodium ion – Na^+



sodium hydrogen sulfate

- “(name of metal) (name of polyatomic ion)" so ionic with a polyatomic ion.
- Sodium is in group 1, so it is +1.
- Sulfate is SO_4^{2-}.
- Assume one H^+.
- Adding one H^+ to SO_4^{2-} yields HSO_4^-.
- Balance the charge.
- **$NaHSO_4$**

Nomenclature Summary

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Binary covalent	A_aB_b	N_2O_5 or CO_2	(prefix unless mono)(name of first element in formula) (prefix)(root of second element)ide	dinitrogen pentoxide or carbon dioxide
Binary ionic	M_aA_b potassium	NaCl or $FeCl_3$ bromide	(name of metal) (root of nonmetal)ide **or** (name of metal)(Roman numeral) (root of nonmetal)ide	sodium chloride or iron(III) chloride
Ionic with polyatomic ion(s)	M_aX_b or $(NH_4)_aX_b$ X = formula of polyatomic ion	Li_2HPO_4 or $CuSO_4$ or NH_4Cl or $(NH_4)_2SO_4$	(name of metal) (name of polyatomic ion) **or** (name of metal)(Roman numeral) (name of polyatomic ion) **or** ammonium (root of nonmetal)ide **or** ammonium (name of polyatomic ion)	lithium hydrogen phosphate or copper(II) sulfate or ammonium chloride or ammonium sulfate
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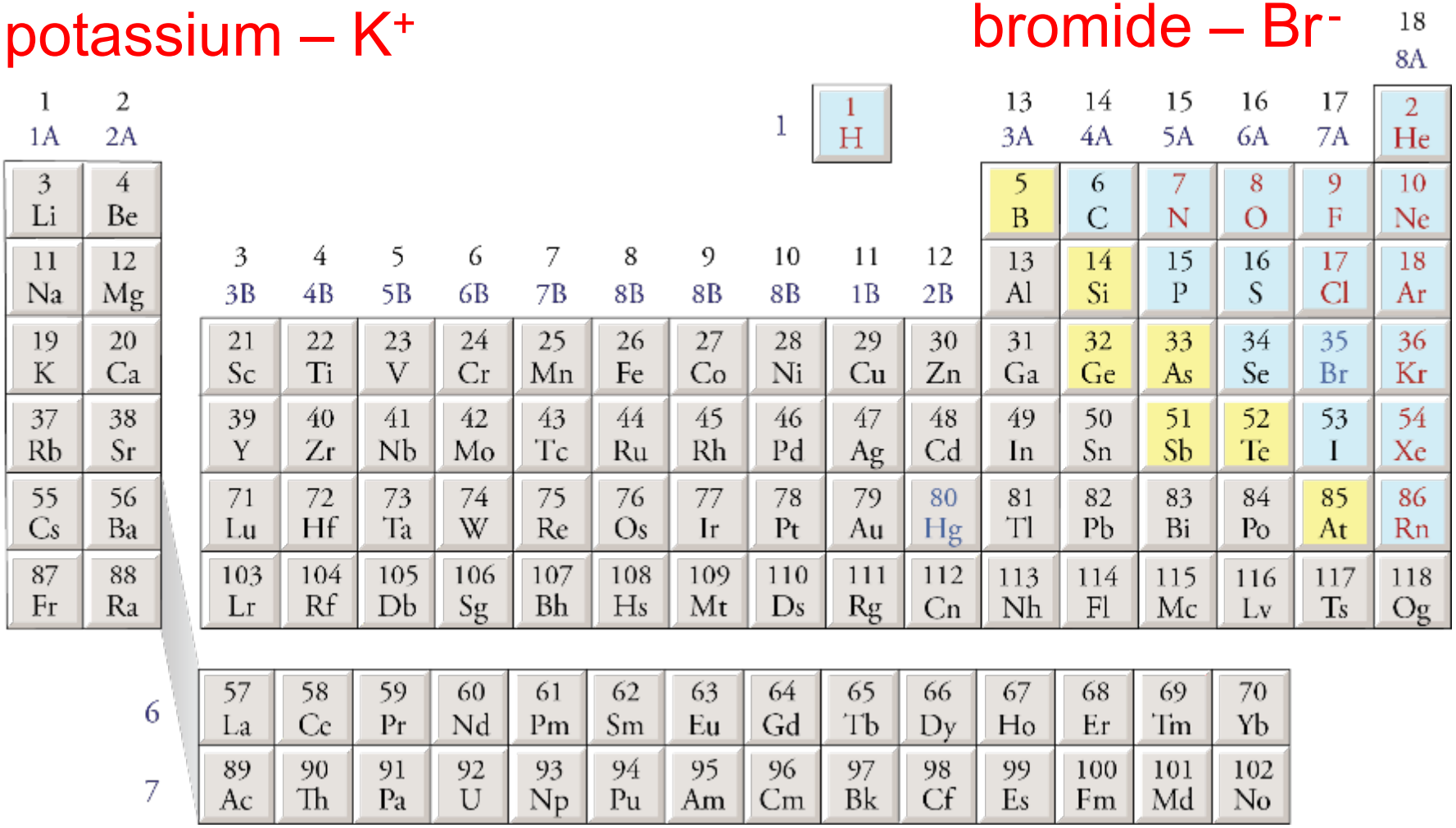
potassium bromide

Periodic Table

potassium – K^+

bromide – Br^-



potassium bromide

- "(name of metal) (root of nonmetal)ide" so binary ionic.
- K (for potassium) is in group 1, so the cation is K^+.
- Br (for bromine) is in group 17, so the anion is Br^-.
- One K^+ balances the charge on one Br^-.
- Potassium bromide is **KBr**

Nomenclature Summary

Type of Compound	General Formula	Examples	General Name	Examples
Binary covalent	A_aB_b	N_2O_5 or CO_2	(prefix unless mono)(name of first element in formula) (prefix)(root of second element)ide	dinitrogen pentoxide or carbon dioxide
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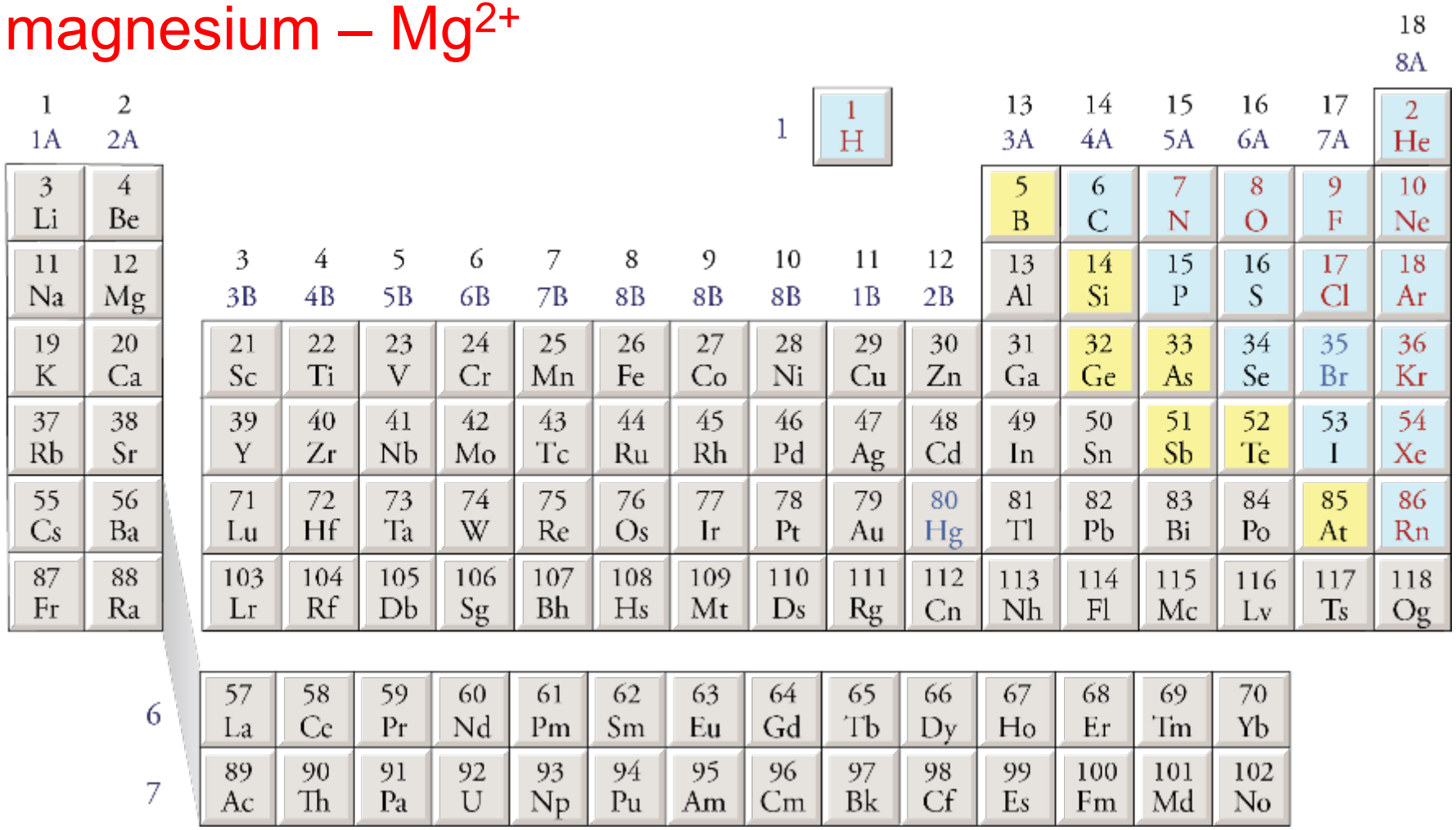
magnesium dihydrogen phosphate

magnesium dihydrogen phosphate

Periodic Table

magnesium – Mg^{2+}



magnesium dihydrogen phosphate

- “(name of metal) (name of polyatomic ion)" so ionic with a polyatomic ion.
- Magnesium is in group 2, so it is +2.
- Phosphate is PO_4^{3-}.
- Adding two H^+ ions to PO_4^{3-} yields $H_2PO_4^-$.
- Balance the charge.
- **$Mg(H_2PO_4)_2$**

Nomenclature Summary

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Oxyacid	$H_aX_bO_c$	HNO_3 or H_2SO_4 or H_3PO_4	(root)ic acid	nitric acid or sulfuric acid or phosphoric acid

hydrofluoric acid

hydrofluoric acid

- “hydro(root)ic acid” so binary acid.
- Formulas for binary acids have the form HX(aq) or H_2X(aq).
- Fluorine atoms only form one bond.
- Hydrofluoric acid is **HF(aq).**

Nomenclature Summary

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diphosphorus tetroxide

diphosphorus tetroxide

- “(prefix)(name of first element in formula) (prefix)(root of second element)ide” so binary covalent.
- di- represents 2.
- Phosphorus is P
- tetra- represents 4.
- ox- is O.
- Diphosphorus tetroxide is **P_2O_4**.

Nomenclature Summary

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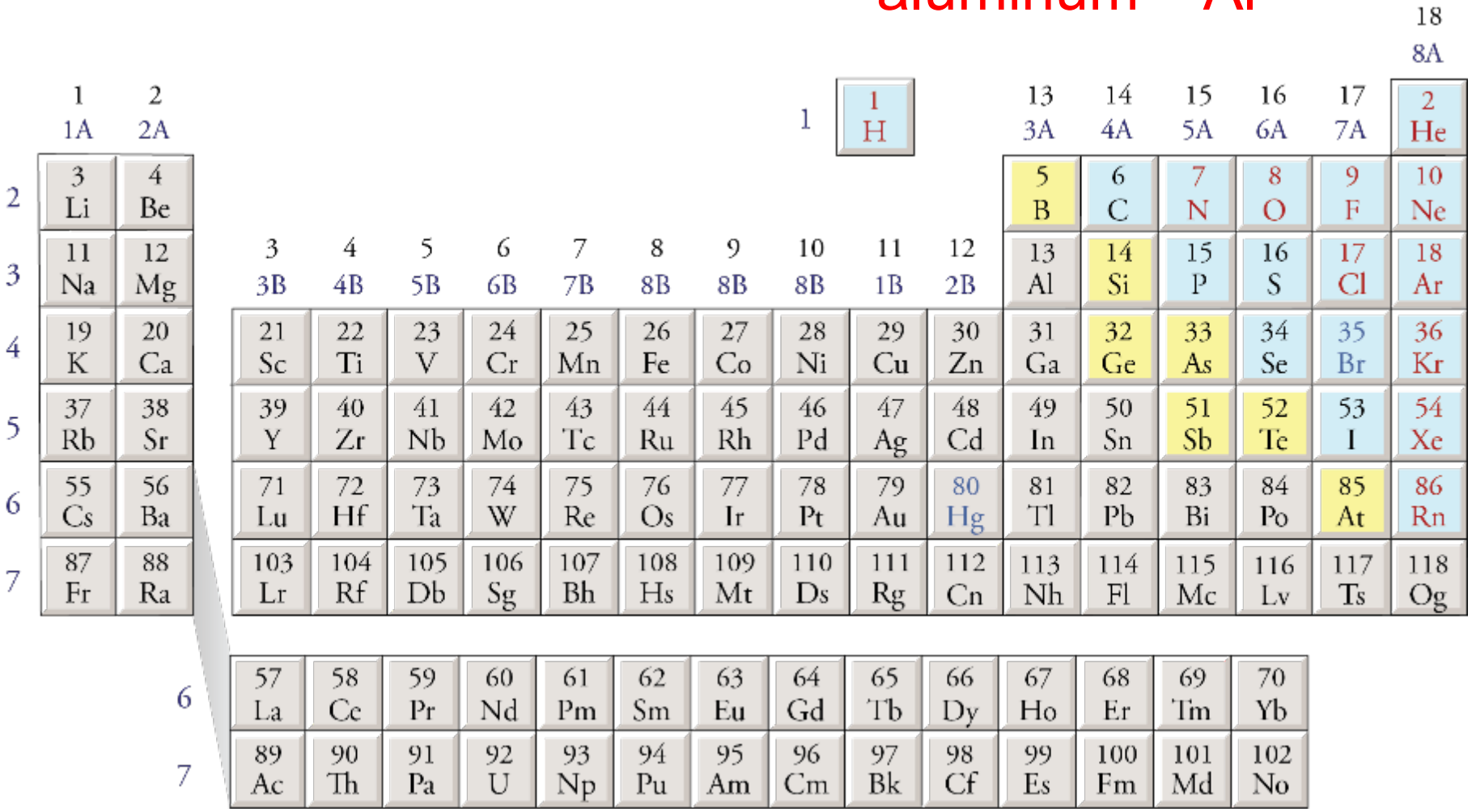
aluminum carbonate

aluminum carbonate

Periodic Table

aluminum – Al^{3+}



aluminum carbonate

- "(name of metal) (name of polyatomic ion)" so ionic with a polyatomic ion.
- Aluminum is Al. It forms Al^{3+} ions.
- Memorize carbonate as CO_3^{2-}.
- Cross the superscripts to get the subscripts for Al^{3+} and CO_3^{2-}.
- **$Al_2(CO_3)_3$**

Nomenclature Summary

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Oxyacid sulfuric acid	$H_aX_bO_c$	HNO_3 or H_2SO_4 or H_3PO_4	(root)ic acid	nitric acid or sulfuric acid or phosphoric acid

sulfuric acid

- “(root)ic acid” without “hydro-” so oxyacid.
- Sulfate is SO_4^{2-}.
- Add enough H^+ ions to neutralize charge.
- Sulfuric acid is $\mathbf{H_2SO_4}$.

Practice

- There are two tools on the textbook website that will allow you to practice the tasks described in this lesson.
  - Identification of types of substances

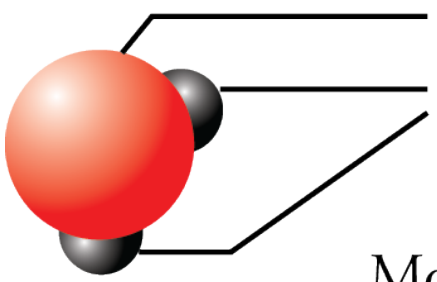
https://preparatorychemistry.com/Type_substance_Canvas.html

  - Converting between names and formulas for compounds

https://preparatorychemistry.com/nomenclature_Canvas.html

Molecular Mass

- Whole = sum of parts
- mass of a molecule = sum of the masses of the atoms in the molecule
- **molecular mass** = the sum of the atomic masses of the atoms in the molecule



Molar mass O:	15.9994 g/mol
Molar mass H:	1.00794 g/mol
	1.00794 g/mol
Molar mass H_2O:	18.0153 g/mol

Molar Mass For Molecular Compounds

- ***Molecular Mass*** = Sum of the atomic masses of atoms in one molecule

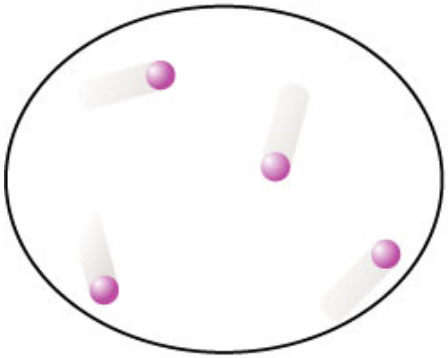
$$\left(\frac{(\text{molecular mass})\,\text{g molecular compound}}{1\,\text{mol molecular compound}}\right)$$

Formula Units

- A ***formula unit*** of a substance is the group represented by the substance's chemical formula, that is, a group containing the kinds and numbers of atoms or ions listed in the chemical formula.
- Formula unit is a general term that can be used in reference to elements, molecular compounds, or ionic compounds.

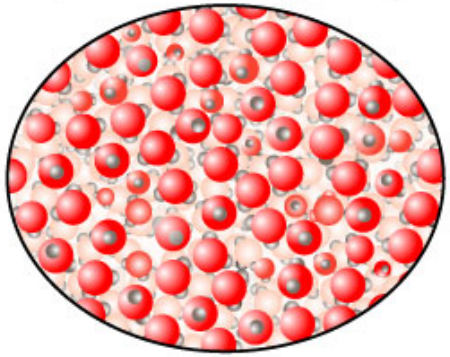
Formula Unit Examples

neon gas
(element)



A formula unit of neon contains one Ne atom.

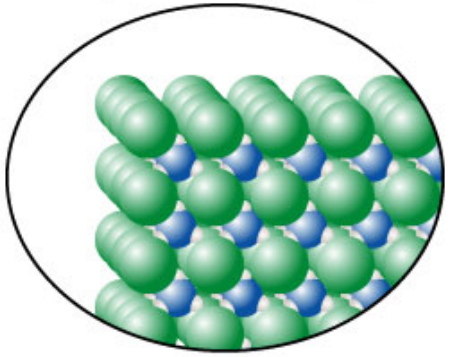
liquid water
(molecular compound)



Liquid water is composed of discrete H_2O molecules.

A formula unit of water contains one oxygen atom and two hydrogen atoms.

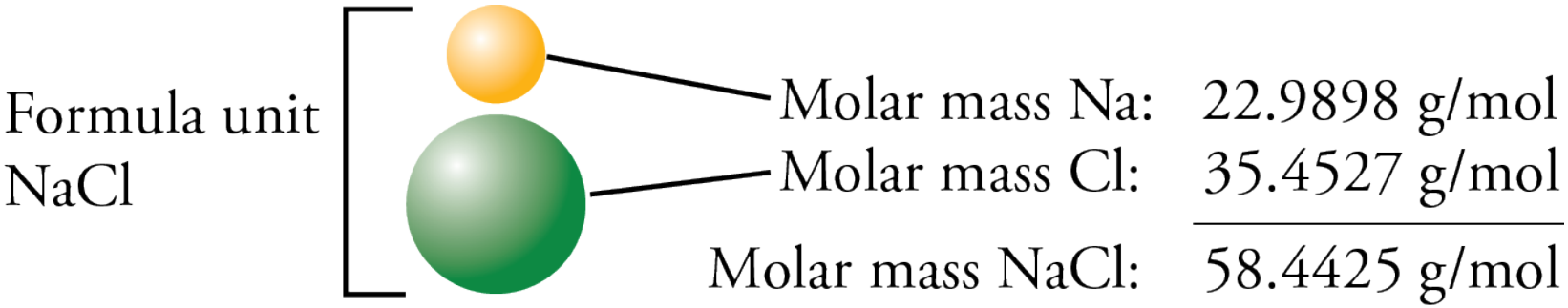
ammonium chloride
(ionic compound)



There are no separate ammonium chloride, NH_4Cl, molecules. Each ion is equally attracted to eight others. A formula unit of ammonium chloride contains one ammonium ion, NH_4^+, and one chloride ion, Cl^-, (or one nitrogen atom, four hydrogen atoms, and one chloride ion).

Formula Mass for Ionic Compounds

- Whole = sum of parts
- Mass of a formula unit = sum of the masses of the atoms in the formula unit
- ***Formula mass*** = the sum of the atomic masses of the atoms in the formula



Molar Mass For Ionic Compounds

- ***Formula Mass*** = Sum of the atomic masses of the atoms in a formula unit

$$\left(\frac{(\text{formula mass})\ \text{g ionic compound}}{1\ \text{mol ionic compound}} \right)$$

Molar Mass Development

From the definition of an unified atomic mass unit, u $\dfrac{12\text{ u C-12}}{1\text{ atom C-12}}$

From the definition of mole $\dfrac{12\text{ g C-12}}{1\text{ mol C-12}}$

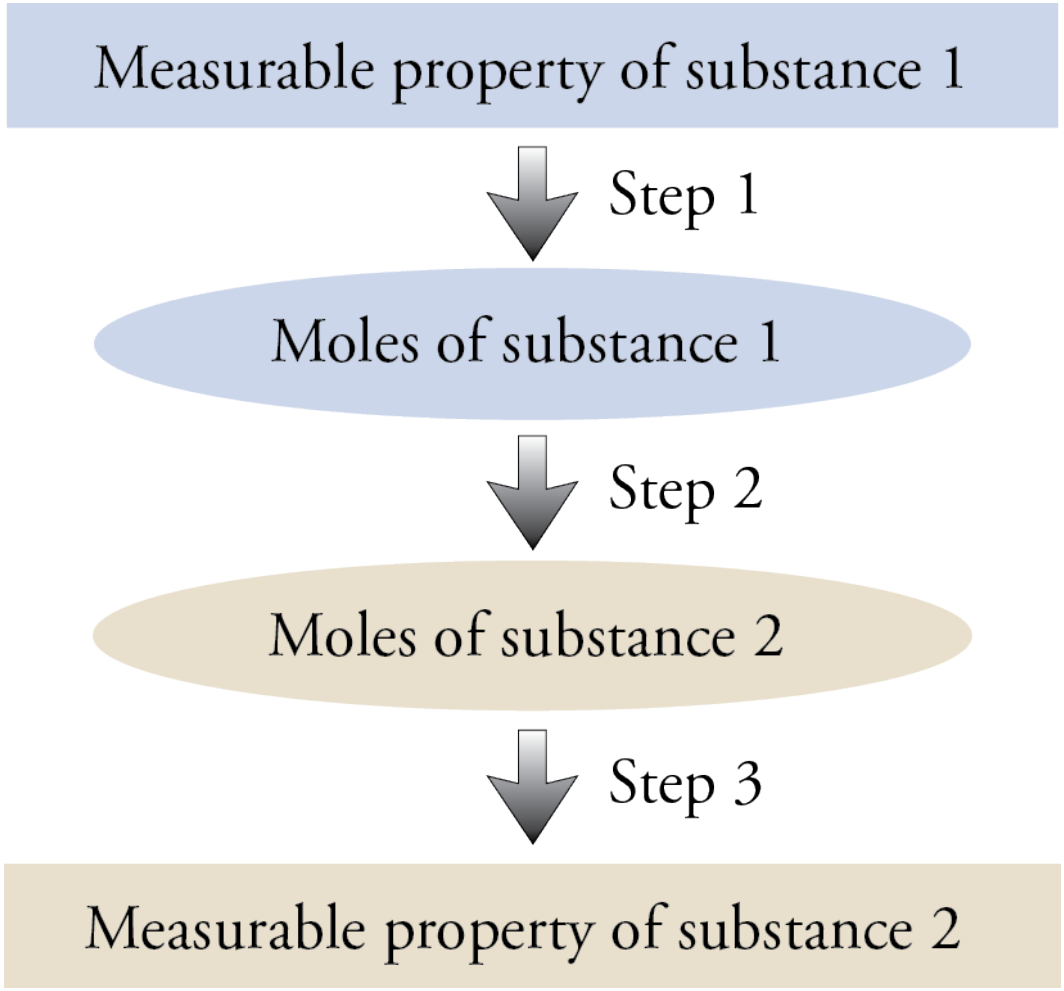
From relative atomic masses

$\dfrac{12.011\text{ g C}}{1\text{ mol C}}$ $\dfrac{24.3050\text{ g Mg}}{1\text{ mol Mg}}$ $\dfrac{15.9994\text{ g O}}{1\text{ mol O}}$ $\dfrac{1.00794\text{ g H}}{1\text{ mol H}}$

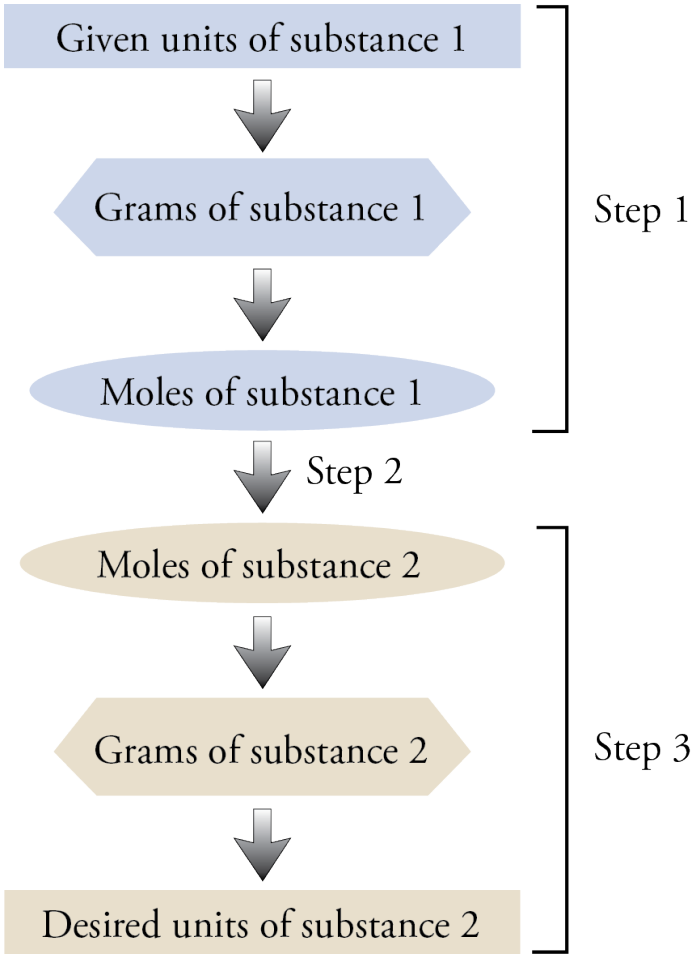
From relative molecular masses $\dfrac{18.0153\text{ g } H_2O}{1\text{ mol } H_2O}$

From relative formula masses $\dfrac{58.4425\text{ g NaCl}}{1\text{ mol NaCl}}$

General Conversions



Units of One Substance to Units of Another



Study Sheets

- Write a description of the “tip-off” that helps you to recognize the type of problem the calculation represents.
- Write a description of the general procedure involved in the particular type of problem.
- Write an example of the type of calculation.

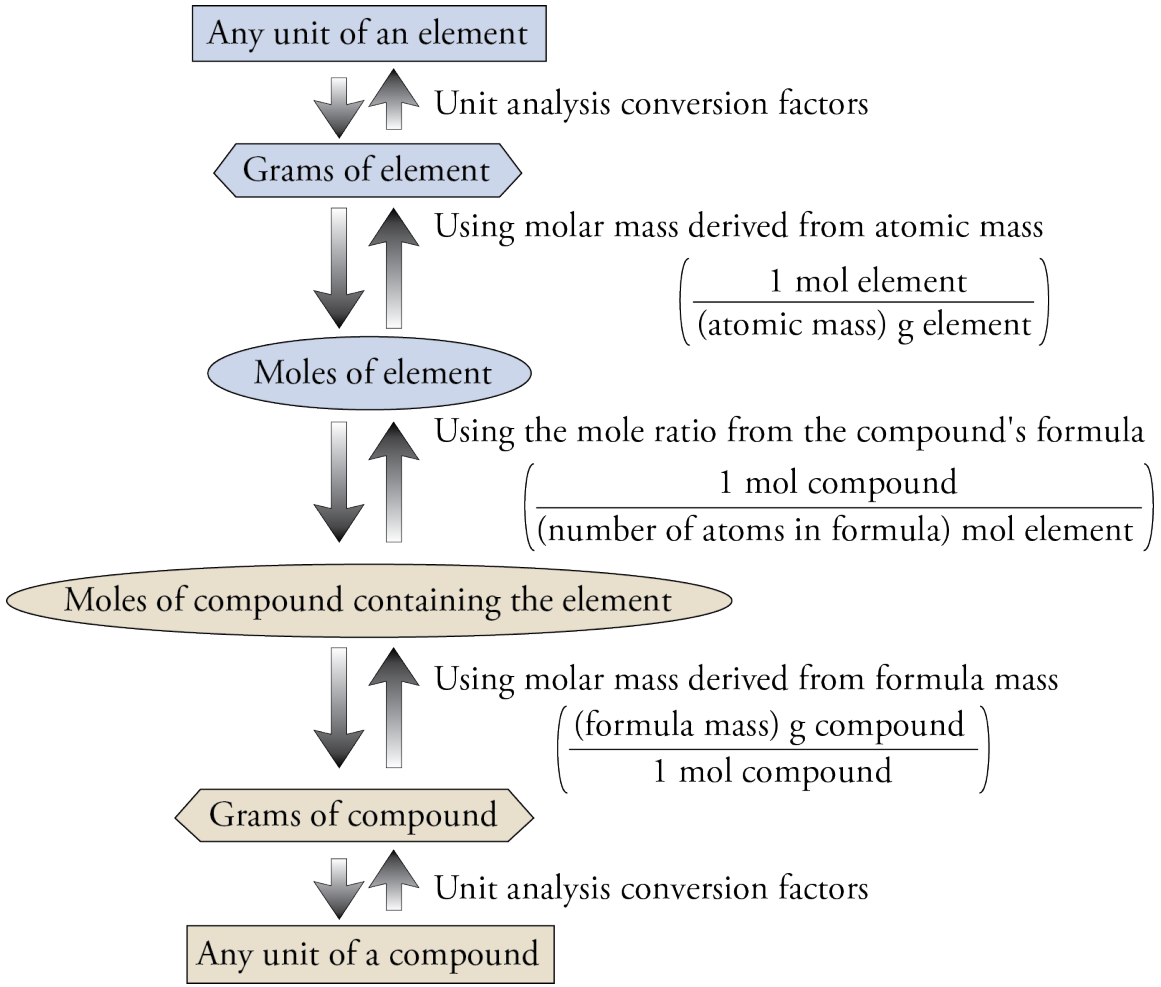
Sample Study Sheet: Converting Between Mass of Element and Mass of Compound Containing the Element

- **Tip-off:** When you analyze the type of unit you have and the type of unit you want, you recognize that you are converting between a unit associated with an element and a unit associated with a compound containing that element.

Sample Study Sheet (2)

- **General Steps**
  - Convert the given unit to moles of the first substance.
  - Convert moles of the first substance to moles of the second substance using the molar ratio derived from the formula for the compound.
  - Convert moles of the second substance to the desired units of the second substance.

Units of Element to Units of Compound



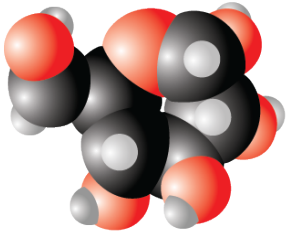
Empirical and Molecular Formulas

- When the subscripts in a chemical formula represent the simplest ratio of the kinds of atoms in the compound, the formula is called an ***empirical formula***.
  - Most ionic compounds are described with empirical formulas.
- A ***molecular formula*** describes the actual numbers of atoms of each element in a molecule.

Examples of Empirical and Molecular Formulas

- Hydrogen peroxide
  - Molecular formula – H_2O_2
  - Empirical formula – HO
- Glucose
  - Molecular formula – $C_6H_{12}O_6$
  - Empirical formula – CH_2O

hydrogen peroxide
molecular formula, H_2O_2,
empirical formula, HO



glucose
molecular formula, $C_6H_{12}O_6$,
empirical formula, CH_2O

Calculating Empirical Formulas

Step 1: If you are not given mass in grams for each element, convert the data you are given to grams of each element.

- This may involve simple unit conversions. For example, you may be given pounds or milligrams, which you convert to grams using unit analysis.
- Sometimes you are given the percentage of each element in the compound. Assume that you have 100 g of compound, and change the numbers for the percentages to grams.

Calculating Empirical Formulas

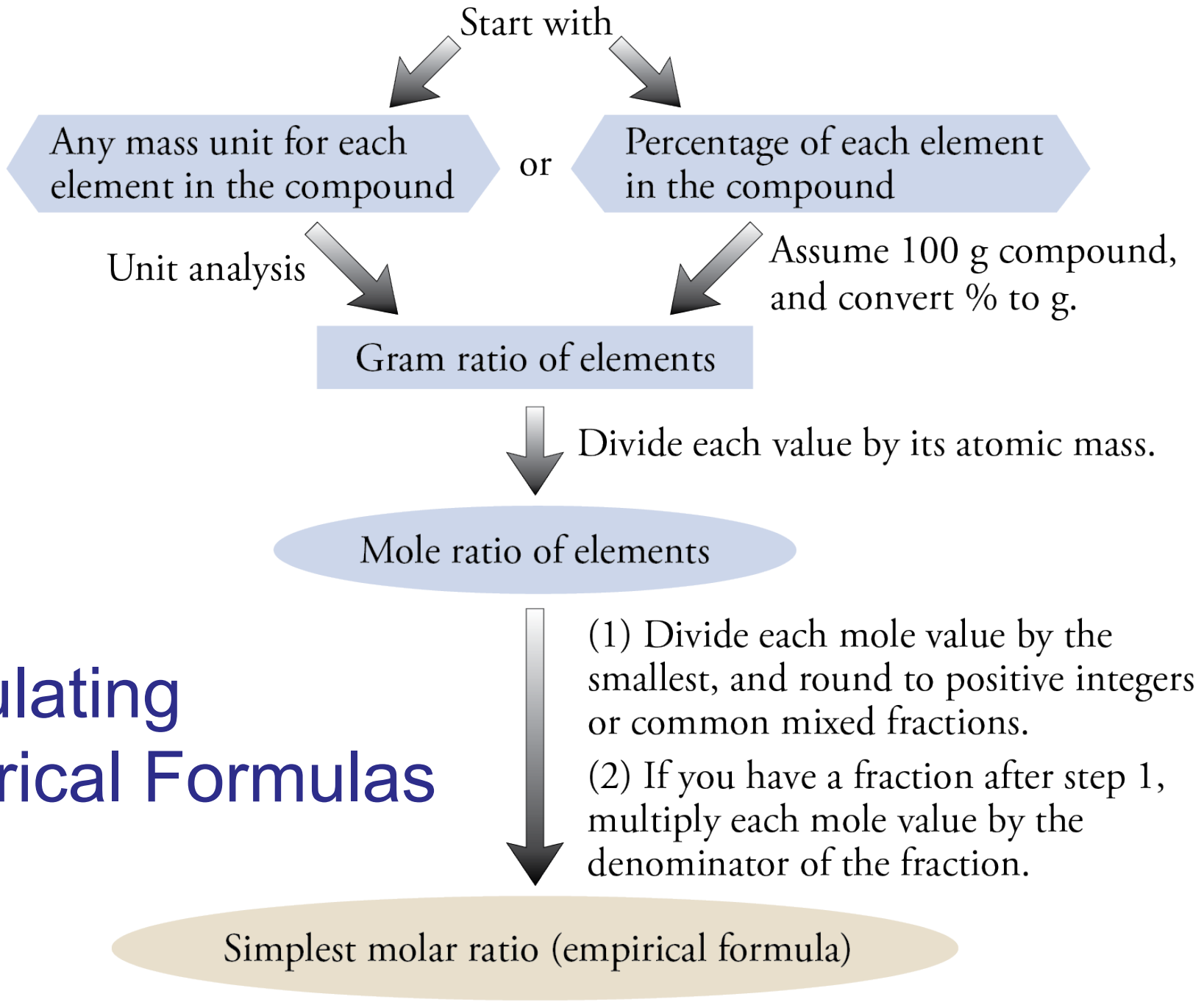
Step 2: Convert grams of each element to moles by dividing by the atomic mass of the element.

Step 3: Divide each mole value by the smallest and round your answers to whole numbers or common mixed fractions.

Step 4: If you have a fraction after the last step, multiply all the mole values by the denominator of the fraction.

Step 5: The resulting mole values correspond to the subscripts in the empirical formula.

Calculating Empirical Formulas



Example Empirical Formula Calculation

- An ionic compound used in the brewing industry to clean casks and vats and in the wine industry to kill undesirable yeasts and bacteria is composed of 35.172% potassium, 28.846% sulfur, and 35.982% oxygen. What is the empirical formula for this compound?
- **Step 1**: Convert percentages to a gram ratio of the elements by assuming 100 g.

  35.172 g K : 28.846 g S : 35.982 g O

Example Empirical Formula Calculation

- An ionic compound used in the brewing industry to clean casks and vats and in the wine industry to kill undesirable yeasts and bacteria is composed of 35.172% potassium, 28.846% sulfur, and 35.982% oxygen. What is the empirical formula for this compound?
- **Step 2**: Convert grams of each element to moles by dividing by the atomic mass of the element.

$$? \text{ mol K} = 35.172 \text{ g K} \left(\frac{1 \text{ mol K}}{39.0983 \text{ g K}} \right) = 0.89958 \text{ mol K}$$

$$? \text{ mol S} = 28.846 \text{ g S} \left(\frac{1 \text{ mol S}}{32.066 \text{ g S}} \right) = 0.89958 \text{ mol S}$$

$$? \text{ mol O} = 35.982 \text{ g O} \left(\frac{1 \text{ mol O}}{15.9994 \text{ g O}} \right) = 2.2490 \text{ mol O}$$

Example Empirical Formula Calculation

- An ionic compound used in the brewing industry to clean casks and vats and in the wine industry to kill undesirable yeasts and bacteria is composed of 35.172% potassium, 28.846% sulfur, and 35.982% oxygen. What is the empirical formula for this compound?
- **Step 3**: Divide each mole value by the smallest and round your answers to whole numbers or common mixed fractions.

$$? \text{ mol K} = 35.172 \text{ g K} \left(\frac{1 \text{ mol K}}{39.0983 \text{ g K}} \right) = 0.89958 \text{ mol K} \div 0.89958 = 1 \text{ mol K}$$

$$? \text{ mol S} = 28.846 \text{ g S} \left(\frac{1 \text{ mol S}}{32.066 \text{ g S}} \right) = 0.89958 \text{ mol S} \div 0.89958 = 1 \text{mol S}$$

$$? \text{ mol O} = 35.982 \text{ g O} \left(\frac{1 \text{ mol O}}{15.9994 \text{ g O}} \right) = 2.2490 \text{ mol O} \div 0.89958 \approx 2\frac{1}{2} \text{ mol O}$$

Example Empirical Formula Calculation

- An ionic compound used in the brewing industry to clean casks and vats and in the wine industry to kill undesirable yeasts and bacteria is composed of 35.172% potassium, 28.846% sulfur, and 35.982% oxygen. What is the empirical formula for this compound?
- **Step 4**: If you have a fraction after the last step, multiply all the mole values by the denominator of the fraction.

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Example Empirical Formula Calculation

- An ionic compound used in the brewing industry to clean casks and vats and in the wine industry to kill undesirable yeasts and bacteria is composed of 35.172% potassium, 28.846% sulfur, and 35.982% oxygen. What is the empirical formula for this compound?
- **Step 5**: The resulting mole values correspond to the subscripts in the empirical formula.

$$K_2S_2O_5$$

Calculating Molecular Formulas

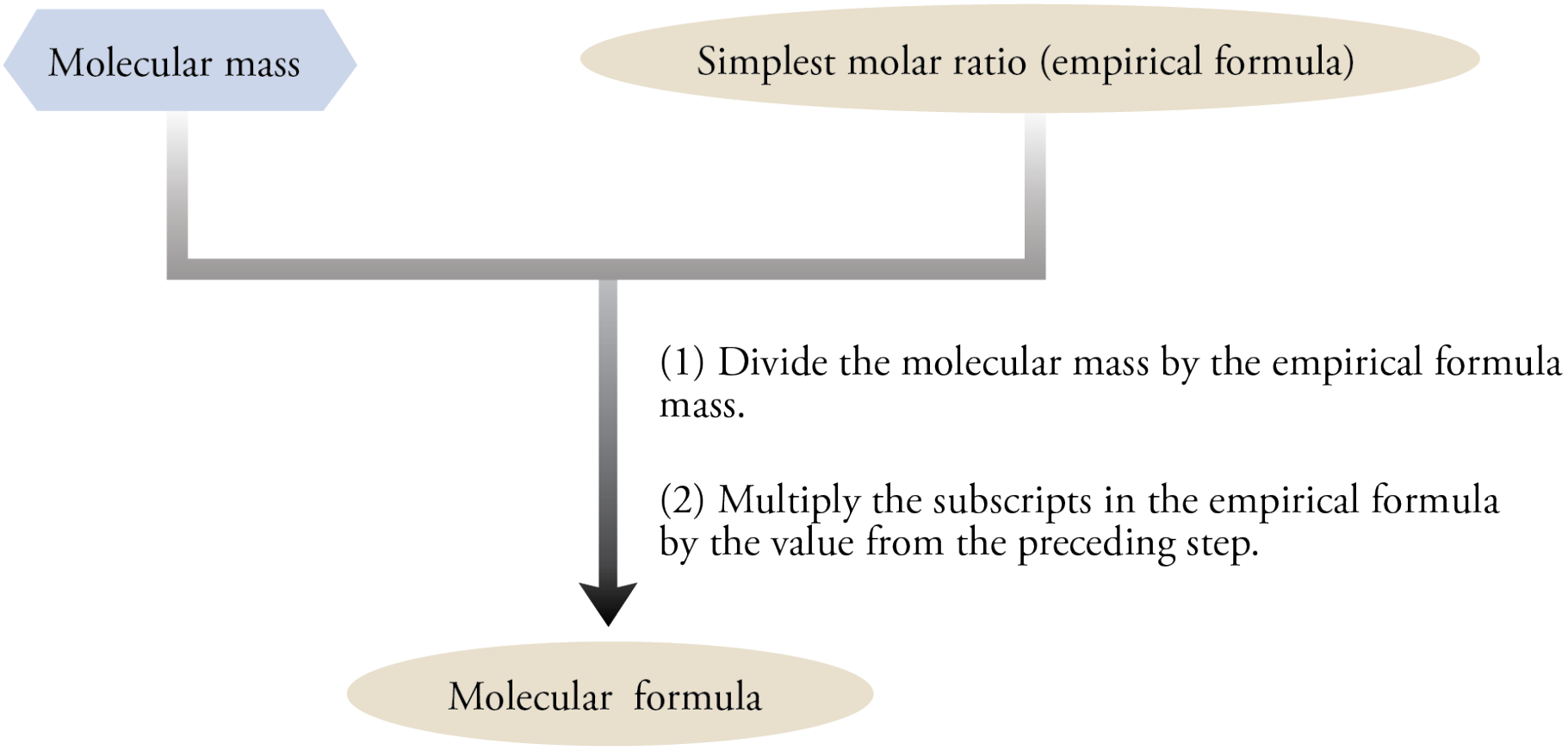
Step 1: If necessary, calculate the empirical formula of the compound from the data given.

Step 2: Divide the given molecular mass by the empirical formula mass.

$$n = \frac{\text{molecular mass}}{\text{empirical formula mass}}$$

Step 3: Multiply each of the subscripts in the empirical formula by *n* to get the molecular formula.

Calculating Molecular Formulas



Example Molecular Formulas

- Compounds called polychlorinated biphenyls (PCBs) have structures similar to chlorinated insecticides, such as DDT. They have been used in the past for a variety of purposes, but because they have been identified as serious pollutants, their use today is limited to insulating fluids in electrical transformers. They have been banned for even this use in the U.S., but because they and the transformers last a long time, they are still in many transformers, even in the United States. One PCB is 39.94% carbon, 1.12% hydrogen, and 58.94% chlorine and has a molecular mass of 360.88. What is its molecular formula?

Example Molecular Formulas

One PCB is 39.94% carbon, 1.12% hydrogen, and 58.94% chlorine and has a molecular mass of 360.88. What is its molecular formula?

Step 1: If necessary, calculate the empirical formula of the compound from the data given.

$$\text{? mol C} = 39.94\ \cancel{\text{g C}}\left(\frac{1\ \text{mol C}}{12.011\ \cancel{\text{g C}}}\right) = 3.325\ \text{mol C} \div 1.11 \approx 3\ \text{mol C} \times 2 = 6\ \text{mol C}$$

$$\text{? mol H} = 1.12\ \cancel{\text{g H}}\left(\frac{1\ \text{mol H}}{1.00794\ \cancel{\text{g H}}}\right) = 1.11\ \text{mol H} \div 1.11 = 1\ \text{mol H} \times 2 = 2\ \text{mol H}$$

$$\text{? mol O} = 58.94\ \cancel{\text{g Cl}}\left(\frac{1\ \text{mol Cl}}{35.4527\ \cancel{\text{g Cl}}}\right) = 1.662\ \text{mol Cl} \div 1.11 = 1\tfrac{1}{2}\ \text{mol Cl} \times 2 = 3\ \text{mol Cl}$$

Empirical formula: $C_6H_2Cl_3$

Example Molecular Formulas

One PCB is 39.94% carbon, 1.12% hydrogen, and 58.94% chlorine and has a molecular mass of 360.88. What is its molecular formula?

Step 2: Divide the given molecular mass by the empirical formula mass.

Step 3: Multiply each of the subscripts in the empirical formula by n to get the molecular formula.

Empirical formula: $C_6H_2Cl_3$ $n = \dfrac{\text{molecular mass}}{\text{empirical formula mass}} = \dfrac{360.88}{180.440} \approx 2$

Molecular formula: $\mathbf{C_{12}H_4Cl_6}$