Professor K

Atoms, molecules, ions
Intro to acids and bases

Close to Home

While Mr. Hunter was not looking, students in his chemistry class used lab tubing to escape, one at a time.

BIG reminder

- Chemistry is another language.
- Getting comfortable with the NOMENCLATURE of chemistry is half the battle.

Lavoisier's law of conservation of mass

- Mercury oxide was heated to produce liquid mercury and oxygen gas.
- He found that the total mass of PRODUCTS = total mass of REACTANTS.
- $2HgO \rightarrow 2Hg + O_2$

Dalton's law of multiple proportions

- An experiment like the electrolysis of water shows us that when elements combine, they do so in the ratio of whole numbers.
- $2H_2 + O_2 \leftarrow\rightarrow 2H_2O$

The atom

- atomic mass unit- an arbitrarily accepted unit equal to 1/12 the mass of a carbon-12 atom
- atomic mass- mass of an element, accounting for the percentage of each naturally occurring ISOTOPE
- atomic number (Z)- number of protons in an atom (and electrons for a neutral atom)
- mass number (A)- number of protons plus neutrons in an atom

The atom

$${}^{A}_{Z}E$$

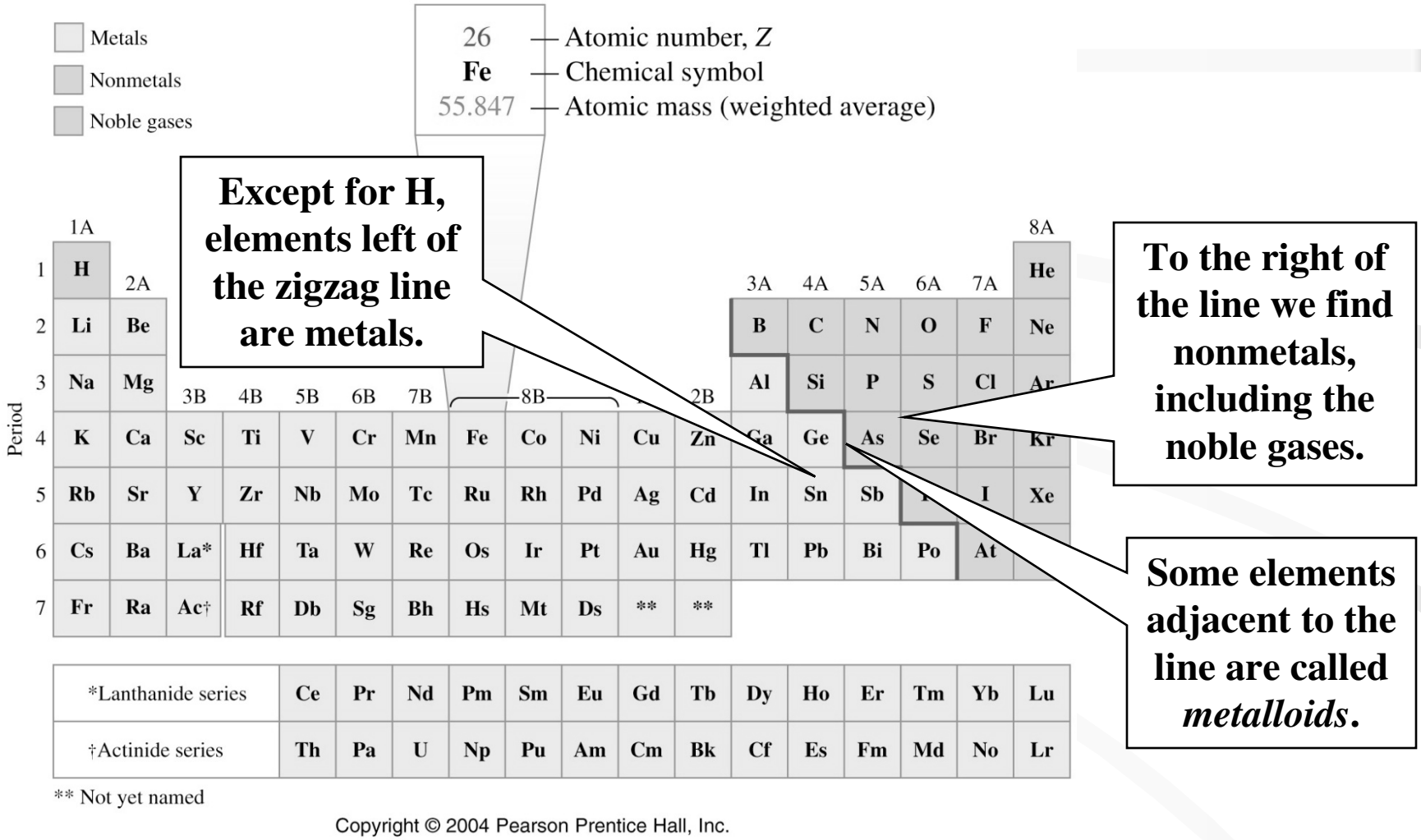
- A is the mass number
- Z is the atomic number
  - Redundant if element symbol is used

- $m_e = 9.1 \times 10^{-31}$ kg
- 1/1836 (0.0005447) that of m_p
- $m_p = 1.67076 \times 10^{-27}$ kg

The periodic table

- Mendeleev- noticed that certain properties had trends and repeated themselves from element to element to element
- arranged elements with similar properties in rows (PERIODS) and columns (GROUPS)
- metals, nonmetals, and metalloids, oh, my!!

The modern periodic table

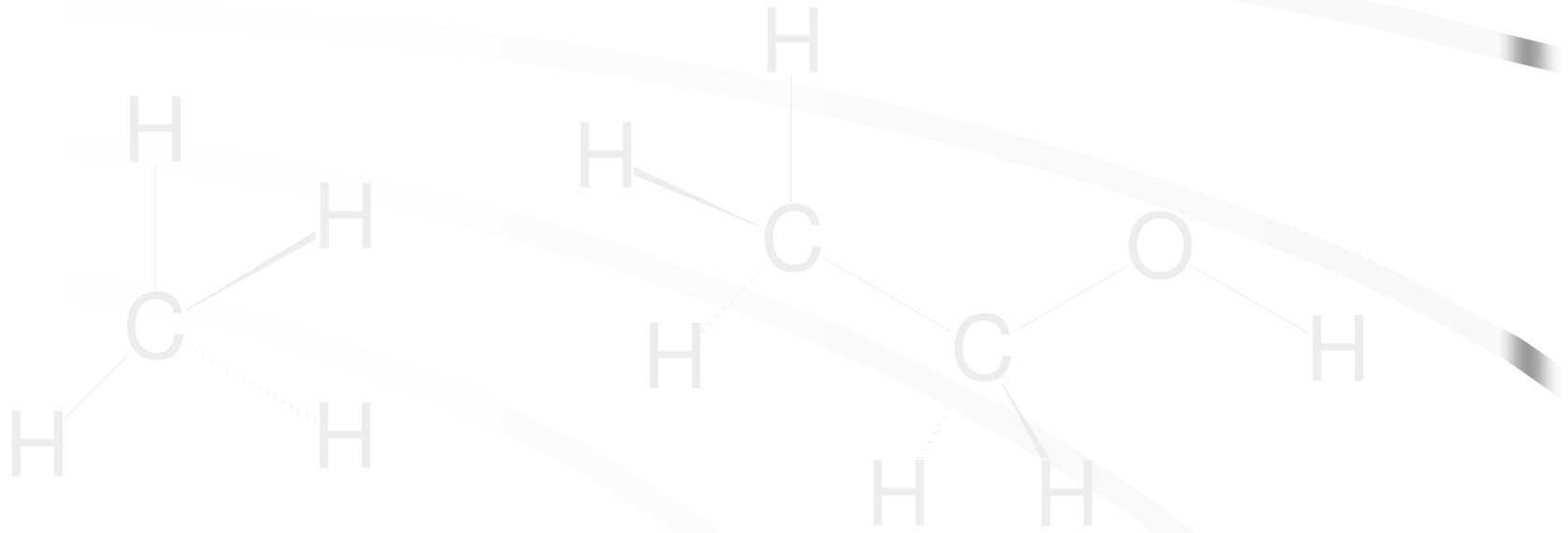


Compounds

- chemical formula- shows actual number of each type of element in a compound....order of elements may give some hint at how they are connected
- empirical formula- the smallest whole number ratio of elements in a compound (ex- CO_2 is the chemical formula for carbon dioxide, but also the empirical formula for C_2O_4 and C_3O_6)
- structural formula

Structural formulas

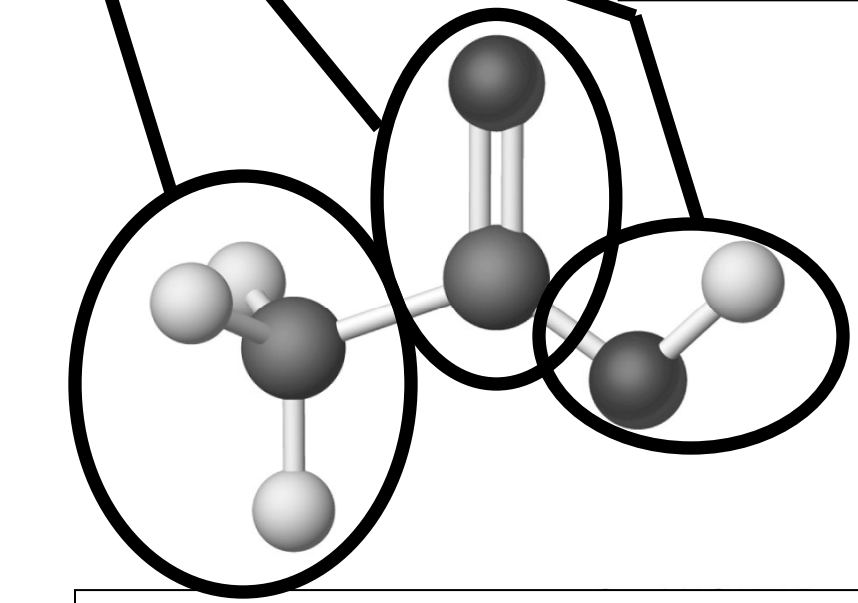
- Give an idea of the shape of the molecule, in 2D or 3D

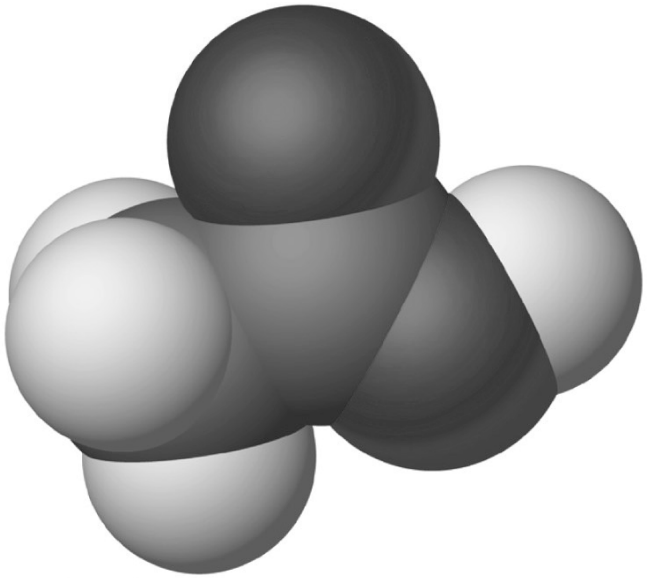


Structural formulas and models

The condensed structural formula for acetic acid is CH_3COOH.

$C_2H_4O_2$: two C atoms, four H atoms, two O atoms.
CH_3COOH shows how the atoms are *arranged*.





Ball-and-stick model **Space-filling model**

Naming compounds

- “Nomenclature” is systematic
- Binary compounds- which element goes first?
- Prefixes and suffixes

Table 2.3 Numeric Prefixes in Names of Binary Molecular Compounds

Number of Atoms	Prefix	Examples[a]
1	mono	NO nitrogen monoxide
2	di	NO_2 nitrogen dioxide
3	tri	N_2O_3 dinitrogen trioxide
4	tetra	N_2O_4 dinitrogen tetroxide
5	penta	N_2O_5 dinitrogen pentoxide
6	hexa	SF_6 sulfur hexafluoride
7	hepta	IF_7 iodine heptafluoride
8	octa	P_4O_8 tetraphosphorus octoxide
9	nona	P_4S_9 tetraphosphorus nonasulfide
10	deca	As_4O_{10} tetraarsenic decoxide

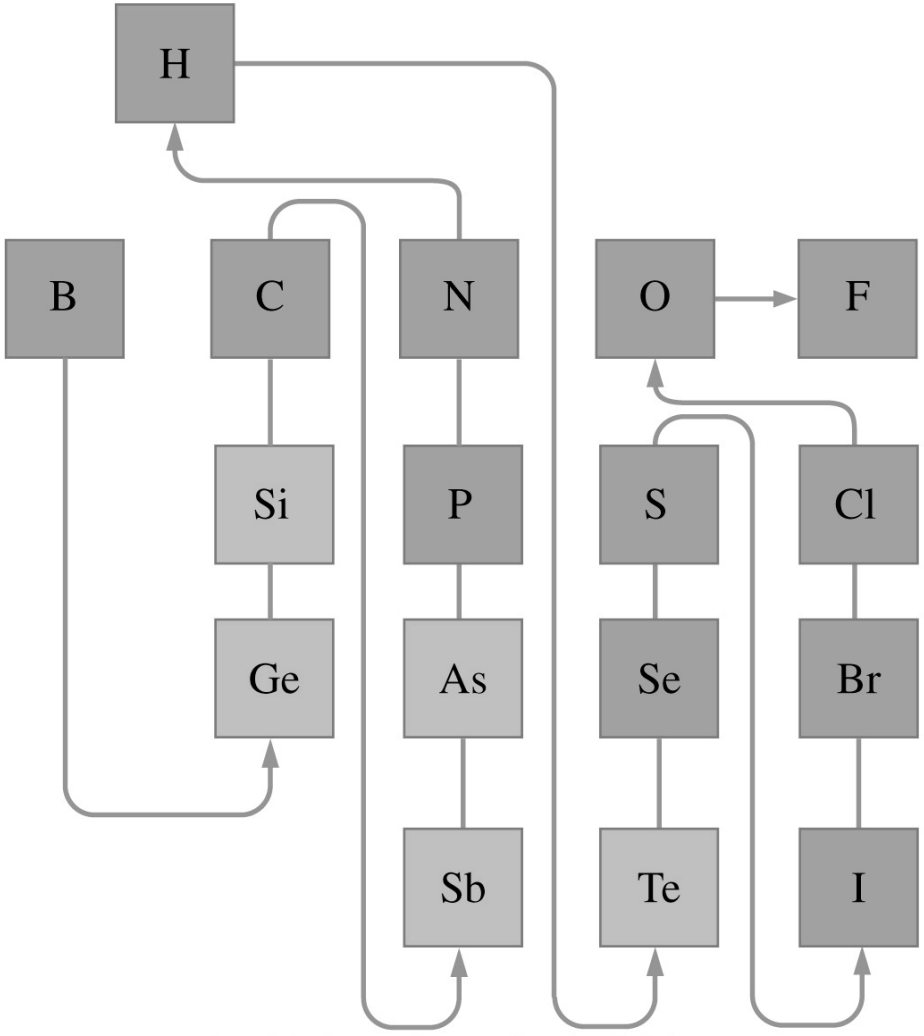
[a] When the prefix ends in "a" or "o" and the element name begins with "a" or "o," the final vowel of the prefix is usually dropped for ease of pronunciation. For example, nitrogen *mon*oxide and not nitrogen *mono*oxide, and

Table 2.4 Some Common Polyatomic Ions

Name	Formula	Typical Compound
Cation		
Ammonium ion	NH_4^+	NH_4Cl
Anions		
Acetate ion	[a]$C_2H_3O_2^-$	$NaC_2H_3O_2$
Carbonate ion	CO_3^{2-}	Li_2CO_3
Hydrogen carbonate ion (or bicarbonate ion)[b]	HCO_3^-	$NaHCO_3$
Hypochlorite ion	ClO^-	$Ca(ClO)_2$
Chlorite ion	ClO_2^-	$NaClO_2$
Chlorate ion	ClO_3^-	$NaClO_3$
Perchlorate ion	ClO_4^-	$KClO_4$
Chromate ion	CrO_4^{2-}	K_2CrO_4
Dichromate ion	$Cr_2O_7^{2-}$	$(NH_4)_2Cr_2O_7$
Cyanate ion	OCN^-	$KOCN$
Thiocyanate ion[c]	SCN^-	$KSCN$
Cyanide ion	CN^-	KCN
Hydroxide ion	OH^-	$NaOH$
Nitrite ion	NO_2^-	$NaNO_2$
Nitrate ion	NO_3^-	$NaNO_3$
Oxalate ion	$C_2O_4^{2-}$	CaC_2O_4
Permanganate ion	MnO_4^-	$KMnO_4$
Phosphate ion	PO_4^{3-}	Na_3PO_4
Hydrogen phosphate ion	HPO_4^{2-}	Na_2HPO_4
Dihydrogen phosphate ion	$H_2PO_4^-$	NaH_2PO_4
Sulfite ion	SO_3^{2-}	Na_2SO_3
Hydrogen sulfite ion (or bisulfite ion)[b]	HSO_3^-	$NaHSO_3$
Sulfate ion	SO_4^{2-}	Na_2SO_4
Hydrogen sulfate ion (or bisulfate ion)[b]	HSO_4^-	$NaHSO_4$
Thiosulfate ion[c]	$S_2O_3^{2-}$	$Na_2S_2O_3$

[a] The acetate ion is also represented as CH_3COO^-. [b] The prefix "bi-" means that the ion contains a replaceable H atom. This should not be confused with the prefix "di-," which means two (usually used to represent a doubling of a simpler unit). [c] The prefix "thio-" means that a sulfur atom has replaced an oxygen atom.

Which element is named first?



Begin with boron and follow the line to determine the order of naming.

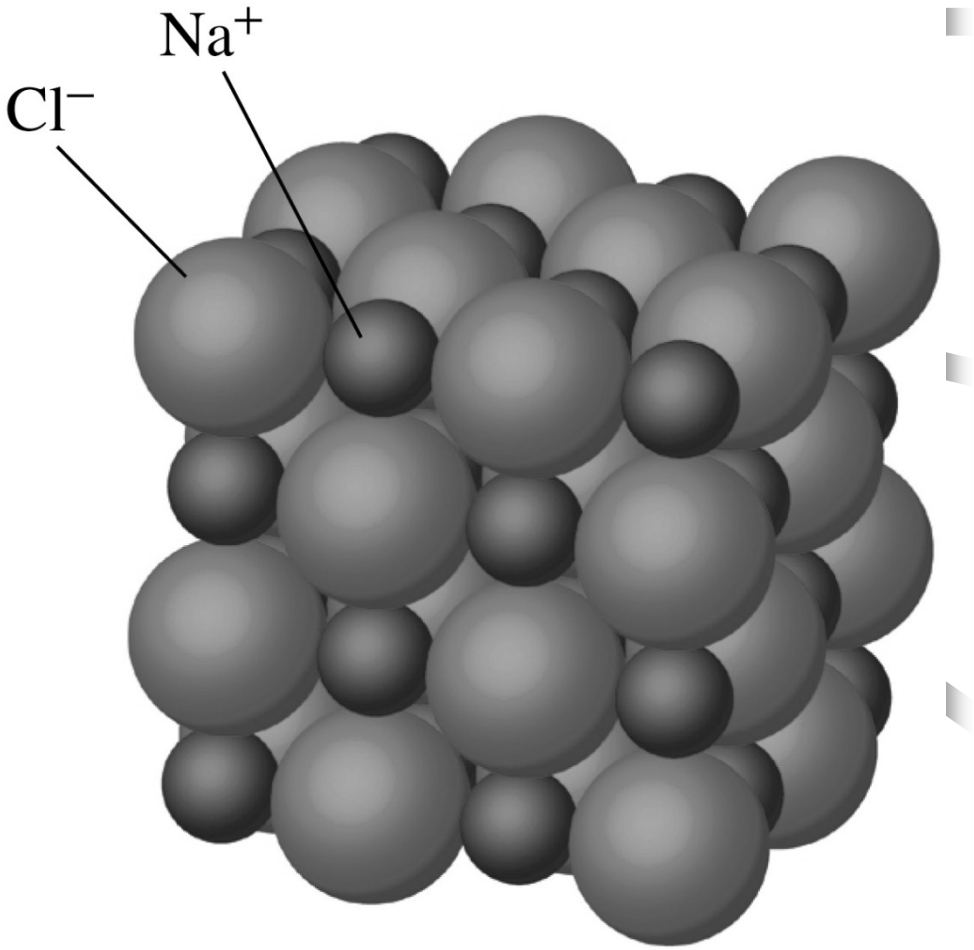
Rule of thumb: the element that is farthest *down* and to the *left* on the periodic table is usually written first.

Ions

- CATIONS ("cat-eye-ons") are POSITIVELY charged atoms or groups
- ANIONS ("an-eye-ons") are NEGATIVELY charged atoms or groups

Ions and ionic compounds

In an IONIC COMPOUND, oppositely charged ions are attracted to each other such that the compound has *no net charge*.

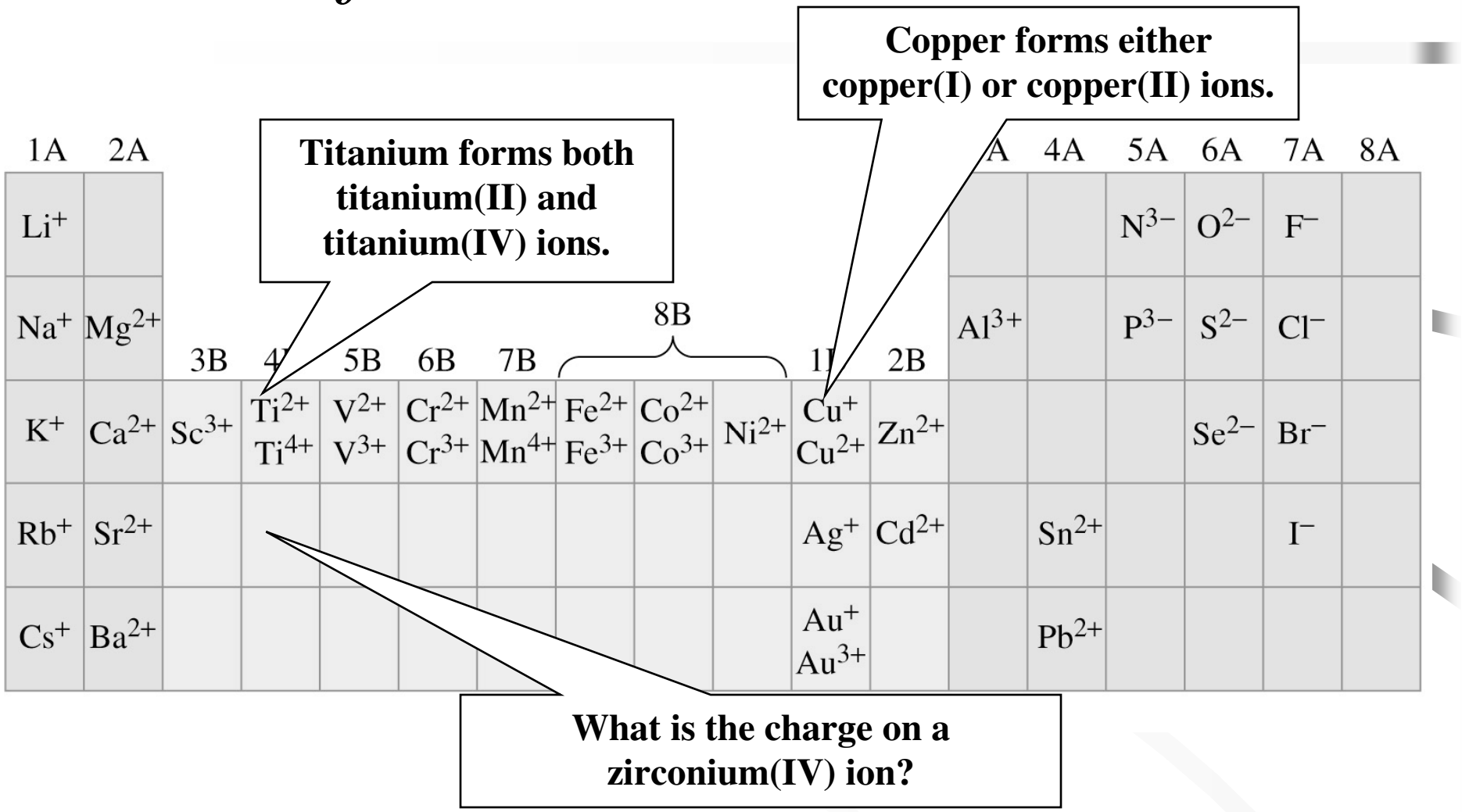


There are no distinct *molecules* of sodium chloride.
NaCl simply consists of sodium ions and chloride ions, regularly arranged.

Monatomic Ions

- Group IA metals form ions of 1+ charge.
- Group IIA metals form ions of 2+ charge.
- Aluminum, a group IIIA metal, forms ions with a 3+ charge.
- Nonmetal ions of groups V, VI, and VII usually have charges of 3–, 2–, and 1–, respectively.
- Group B metal ions (transition metal ions) often have more than one possible charge. A Roman numeral is sometimes used to indicate the actual charge.
- A few transition elements have only one common ion (Ag, Zn, Cd), and a Roman numeral is not often used.

Symbols and periodic table locations of some monatomic ions



Hydrates

- Compounds which exist with one or more molecules of water in the FORMULA UNIT (not a topic we will discuss in depth)
- Eg- $Mg(SO_4)\bullet 5H_2O$

Acids, bases, salts – an intro

- Arrhenius definitions
  - Acids dissolve in water releasing H^+
  - Bases dissolve in water releasing OH^-
- Bronsted-Lowry definitions
  - Acids are proton donors
  - Bases are proton acceptors
- Lewis definitions
  - Acids are electron pair acceptors
  - Bases are electron pair donors

Acids

- Taste sour, if diluted with enough water to be tasted safely.
- May produce a pricking or stinging sensation on the skin.
- Turn the color of litmus or indicator paper from blue to red.
- React with many metals to produce ionic compounds and hydrogen gas.
- Also react with bases, thus losing their acidic properties.

Bases

- Taste bitter, if diluted with enough water to be tasted safely.
- Feel slippery or soapy on the skin. (WHY?)
- Turn the color of litmus or indicator paper from red to blue.
- React with acids, thus losing their basic properties.

Today's mantra

Acid plus base makes salt plus water

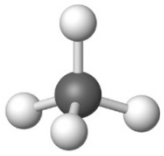
Organic compounds

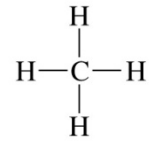
- *Compounds based on carbon*
- May have other elements, including metals, and still be called organic
- IMHO: The word ORGANIC now wins the prize for the most abused word in the English language... it has absolutely nothing to do with how “natural” something is.

Alkanes

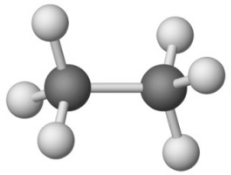
- Contain only C and H- general formula C_nH_{2n+2}
- Example- octane...When burned in an ideal world, alkanes produce only water and carbon dioxide... unfortunately, the world we live in is not ideal
- CYCLIC alkanes have the carbon chain in a ring, and have the general formula C_nH_{2n}
- Become comfortable with the "line drawing" shorthand of structural formulas
- ALL carbons must have 4, and exactly 4, bonds to them (4 single bonds, 2 single and a double, 1 single and a triple, etc.)

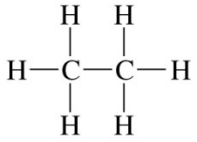
Alkanes



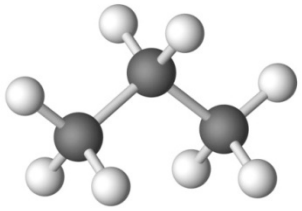


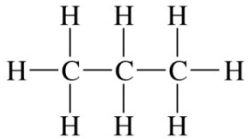
Methane, CH_4





Ethane, C_2H_6





Propane, C_3H_8

- Octane?

Table 2.6 Word Stems Indicating the Number of Carbon Atoms in Simple Organic Molecules

Stem	Number of C Atoms
meth-	1
eth-	2
prop-	3
but-	4
pent-	5
hex-	6
hept-	7
oct-	8
non-	9
dec-	10

Alkenes

- Contain only C and H with at least one double bond in the carbon chain- general formula C_nH_{2n}
- Example- ethylene used to make polyethylene bottles

Isomers have the same formula but different structures

- Structural isomers have the atoms connected differently

  CH_3OCH_3 and CH_3CH_2OH

- Geometric isomers have atoms arranged differently around a double bond

  (remember cis and trans?)

  (ever hear of E and Z?)

  (how about L and D? (actually different- *optical* isomers))

Alkynes

- Contain only C and H with at least one triple bond in the carbon chain- general formula C_nH_{2n-2}
- Example- acetylene used for welding

Functional groups

- Groups of atoms seen in many compounds... these groups of atoms give the resulting compounds similar properties and/or reactivity

Alcohols

- General formula R-OH, where R is any organic group
- Examples:
  - methanol (methyl alcohol)
    - "wood alcohol"- causes blindness/death at very low dosages
  - ethanol (ethyl alcohol)
    - drinking alcohol
  - isopropanol (isopropyl alcohol)
    - rubbing alcohol

Ethers

- General formula R-O-R', where R and R' may be the same organic groups or different
- Examples
  - engine starter
  - the anesthetics of old

Aldehydes

- General formula R-CO-H, where there is an oxygen with a double bond to C attached to a single R group (and an H)
- Example- formaldehyde (HCOH)

Ketones

- General formula R-CO-R', where there is an oxygen with a double bond to C attached to two (same or differing) R groups
- Example- acetone (paint thinner/nail polish remover) (CH_3COCH_3)

Carboxylic (organic) acids

- General formula R-COOH, where there is an oxygen with a double bond to C and an OH attached to the same C
- Examples:
  - acetic (ethanoic) acid (vinegar) (CH_3COOH)
  - Carbonic acid (H_2CO_3) is not a standard carboxylic acid, but is ubiquitous in nature

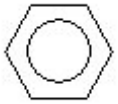
Esters

- General formula R-COOR', where there is an oxygen with a double bond to C and an OR' group attached to the same C
- Example- almond and vanilla extract

Amines

- General formula R-NH_2
- Examples:
  - ammonia, a.k.a. Windex©, or glass cleaner
  - trimethylamine (fishy smell)
- Question: Is $NH_3(g)$ the blue stuff in the Windex© bottle (or even the clear generic)?
  (You might need to know this in the lab...)

Aromatics (quick preview)

- The aromatic functional group normally refers to C_6H_5 bonded to something
- Represented as Ar,  or 

- More generally, something aromatic (so called originally due to their odor) has an alternating series of double and single bonds