CHEM 205 section 03

LECTURE #7 Thurs. Jan.24, 2008

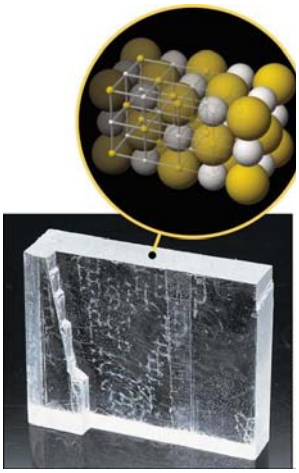
ASSIGNED READINGS:

TODAY'S CLASS: up to 3.4

NEXT CLASS: **finish Ch.3, start Ch.4**

3.3 Ionic Compounds: Formulas, Names & Properties

An ION
= atom or group of atoms with *net* positive or negative charge



In ionic compounds:

- Ions arranged in *crystal lattice*
  - ordered, closely packed, 3-D array
  - each ion surrounded by nearest-neighbours of opposite charge
- Charges *countered*, not cancelled
- Crystal as a whole is neutral

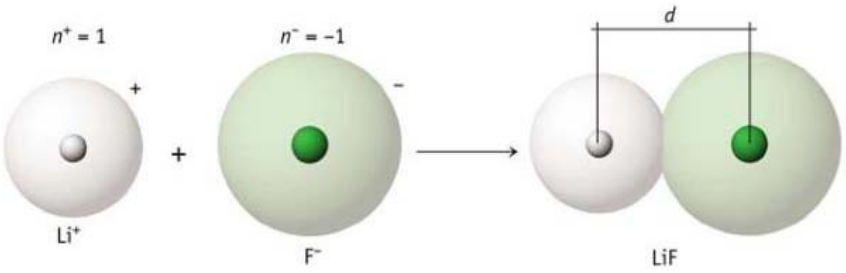
Fig.3.11

IONIC bonding = electrostatic attraction between oppositely charged IONS

COULOMB'S LAW: governs force of attraction

$$F = k\,\frac{(n^+ e)(n^- e)}{d^2}$$

n+ n- = charges on cation & anion
e = actual charge on an electron
d = distance between ion centres
k = a proportionality constant



ion charges ↑ ⇨ attraction ↑
ion sizes ↑ ⇨ attraction ↓

Learn about estimating ion sizes later…

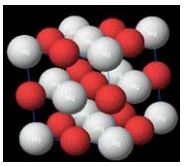
(3)

Properties of ionic compounds

- High melting points
  - Ions must overcome MANY individual ionic bonds (high E needed)

NaCl
Na^+ & Cl^- ions
m.p. 804 °C

MgO
Mg^{2+} & O^{2-} ions
m.p. 2800 °C



- Brittle, crystalline solids
  - Impact ⇨ push like charges together ⇨ repulsion ⇨ CLEAVAGE

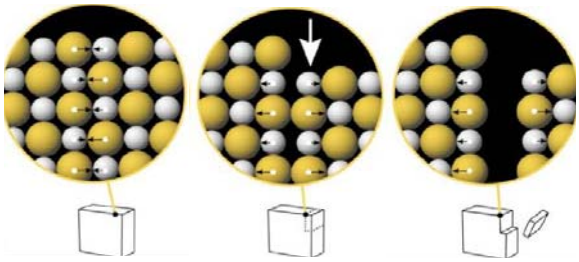
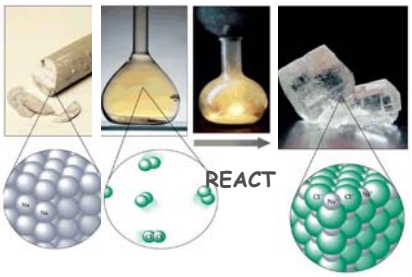


Fig.3.12

Where do ions come from? *…atoms lose / gain electrons*

		# p⁺ = # e⁻	NEUTRAL ATOM
Metals	Lose e⁻ ⇨	# p⁺ > # e⁻	POSITIVE "CATION"
Nonmetals	Gain e⁻ ⇨	# p⁺ < # e⁻	NEGATIVE "ANION"



Sodium + chlorine → sodium chloride

$2\ Na(s) + Cl_2(g) \rightarrow 2\ NaCl(s)$

Keeping track of the electrons:

$2\ Na \rightarrow 2\ Na^+ + 2\ e^-$

$Cl_2 + 2\ e^- \rightarrow 2\ Cl^-$

$2\ Na(s) + Cl_2(g) \rightarrow 2\ NaCl(s)$

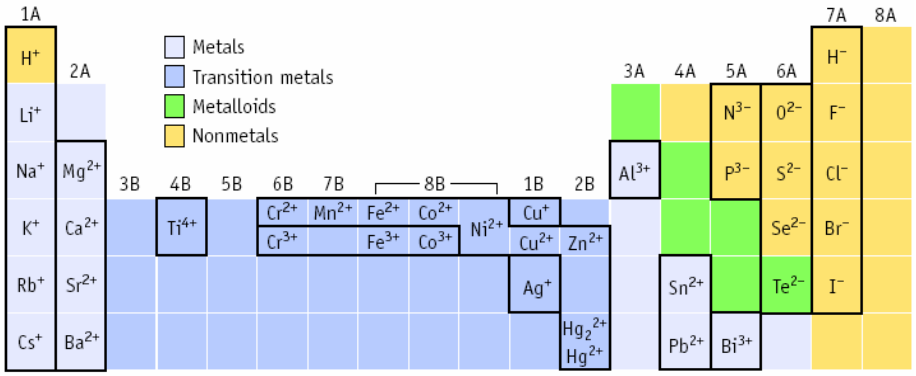
Atom	Loss/Gain	# p⁺	# e⁻	CHARGE	Name	Symbol
$^{23}_{11}Na$	Lose 1 e⁻	11	10	+1	Sodium ion	Na^+
$^{35}_{17}Cl$	Gain 1 e⁻	17	18	-1	Chloride ion	Cl^-

Predicting ion charges: for monatomic (single atom) ions

- Main group elements: lose/gain to achieve empty/full valence
  - metals → cations: $M^{(group\#)+}$
  - nonmetals → anions: $E^{(8-group\#)-}$

Sn & Pb also form 4+ cations

- Transition metals: more possibilites, harder to predict
  - M^{2+} & M^{3+} are common (see below)



Formulas of ionic compounds: ZERO NET CHARGE

- **Principle of electroneutrality:**
  Ions present in ratio that yields zero net charge in crystal
- USEFUL: can predict formula if know ion charges
  - trick: cross-multiply charges to find common denominator yields formula with correct balance of + & - charges

Ion Combination M^{m+} & E^{n-}	Ion ratio required for neutrality  since $(nxm)^+ + (mxn)^- = 0$	Compound's formula M_nE_m
K^+ & N^{3-}	[3 x (1+)] + [1 x (3-)] = 0	K_3N
Ti^{4+} & O^{2-}		
		Al_2O_3

(7) An ionic compound's NAME indicates BARE ESSENTIALS:
1.) identities of ions present
2.) sufficient information to deduce # of each

Naming ions: monatomic cations ⇨ element name

METAL - n e^- → M^{n+}

- n = Group #
- charge # 1st, then sign

Na^+ sodium ion
Al^{3+} aluminum ion

Fe^{2+} iron(II) ion
Fe^{3+} iron(III) ion

Specify charge IF >1 charge possible
i.e., transition metals…

FYI: old system for metals with variable charge
Higher charge: Latin root + "-ic"
Lower charge: Latin root + "-ous"

Cu^{2+} copper(II) = cupric ion, Fe^{3+} iron(III) = ferric ion
Cu^+ copper(I) = cuprous ion, Fe^{2+} iron(II) = ferrous ion

NOTE symbol convention: charge written with # first, *then* sign

Naming ions: monatomic anions ⇨ element root + "-ide"

NONMETAL + n e^- → E^{n-}

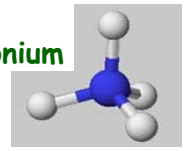
- n = (8 - Group #)
- charge # 1st, then sign

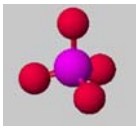
Group 4A	Group 5A	Group 6A	Group 7A
C^{4-}	N^{3-}	O^{2-}	F^-
	P^{3-}, phosphide	S^{2-}	Cl^-
		Se^{2-}, selenide	Br^-
		Te^{2-}, telluride	I^-

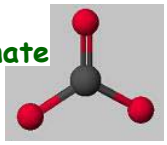
NOTE symbol convention: charge written with # first, *then* sign

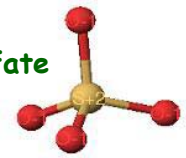
Some ions are polyatomic

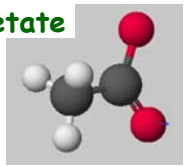
- Like molecules:
  - covalent bonding within unit
- Unlike molecules:
  - **net charge on whole unit** (superscript…)
  - *WHY? Sometime during its formation, an atom gained/lost electrons*

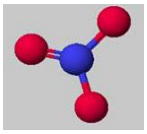
Ammonium 

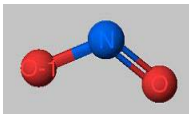
Phosphate 

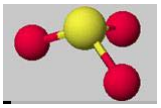
Carbonate 

Sulfate 

Acetate 

Nitrate 

Nitrite 

Sulfite 

Naming ionic compounds: 1st cation, then anion

a) Binary Ionic Compounds (composed of 2 elements)

Specify charge ONLY if variable

Formula	*Name*
$CoCl_3$	
	potassium phosphide
$FeBr_2$	

b) Compounds containing polyatomic ions (memorize – next…)

Brackets & subscript to indicate **multiple polyatomic ions** →

…do NOT use ( ) for monatomic ions

Formula	*Name*
$(NH_4)_2CO_3$	
	sodium phosphate

CHEMISTS SPECIFY ONLY AS MUCH AS NECESSARY IN NAMES:

- ionic compounds: never specify # of each ion present
- reader must apply the concept of electroneutrality

Table 3.1 • Formulas and Names of Some Common Polyatomic Ions

Formula	Name	Formula	Name
CATION: Positive Ion			
NH_4^+	ammonium ion		
ANIONS: Negative Ions	Many polyatomic anions contain OXYGEN: "oxoanions"		
Based on a Group 4A element			
CN^-	cyanide ion	***Based on a Group 7A element***	
$CH_3CO_2^-$	acetate ion	ClO^-	hypochlorite ion
CO_3^{2-}	carbonate ion	ClO_2^-	chlorite ion
HCO_3^-	hydrogen carbonate ion (or bicarbonate ion)	ClO_3^-	chlorate ion
		ClO_4^-	perchlorate ion
Based on a Group 5A element		***Based on a transition metal***	
NO_2^-	nitrite ion	CrO_4^{2-}	chromate ion
NO_3^-	nitrate ion	$Cr_2O_7^{2-}$	dichromate ion
PO_4^{3-}	phosphate ion	MnO_4^-	permanganate ion
HPO_4^{2-}	hydrogen phosphate ion		
$H_2PO_4^-$	dihydrogen phosphate ion		
Based on a Group 6A element			
OH^-	hydroxide ion		
SO_3^{2-}	sulfite ion		
SO_4^{2-}	sulfate ion		
HSO_4^-	hydrogen sulfate ion (or bisulfate ion)		

Oxoanions *aka* oxyanions:
- negative charge on O atom(s)
- can cancel out -ve charge by making covalent bond to H^+

Polyatomic ions containing oxygen: "oxoanions"

- **Trend for nonmetals:** set of oxoanions varying # of Os
  prefix/suffix to specify # of Os

Increasing oxygen content ↑

Per_____ate
_____ate
_____ite
Hypo_____ite

IO_4^-	Periodate ion
IO_3^-	Iodate ion
IO_2^-	Iodite ion
IO^-	Hypoiodite ion

- Oxoanions containing hydrogen:
  - **add "hydrogen" before name of oxoanion**
  - hydrogen phosphate HPO_4^{2-}
  - dihydrogen phosphate $H_2PO_4^-$

- Many have common names too: ***using prefix "bi"***
  - hydrogen sulfate HSO_4^- *bisulfate ion*
  - hydrogen sulfite HSO_3^- *bisulfite ion*
  - hydrogen carbonate HCO_3^- *bicarbonate*

Polyatomic ion memory aid: by central atom, on P.Table

- Memorize **unique ions** & **-ates** ⇨ deduce rest using oxoanion rules
  if add H^+, reduce -ve charge

	4A Carbon	5A Nitrogen	6A Oxygen	7A Halogens
Transition metals	CH_3COO^- CN^- CO_3^{2-}	NH_4^+ NO_3^- NO_2^-	OH^-	
CrO_4^{2-} $Cr_2O_4^{2-}$ MnO_4^-		PO_4^{3-} PO_3^{3-}	SO_4^{2-} SO_3^{2-}	ClO_4^- ClO_3^- ClO_2^- ClO^- (same for Br & I)

Some practice with polyatomic ions

Compound	Ion Combination	Formula
		$(NH_4)_2SO_3$
silver perchlorate		
		$Ni(HCO_3)_2$
iron (II) phosphate *OR* ferrous phosphate		

NAMES OF COMPOUNDS CONTAIN THE BARE ESSENTIALS:

- never specify # of each ion present
- specify charge for variable-charge transition metals
- deduce ion ratio by applying concept of electroneutrality

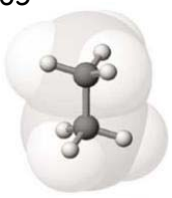
3.4 Molecular compounds: Formulas, Names and Properties

- Atoms bound together by covalent bonds
- Molecular compounds <u>generally contain only nonmetals</u>
  - Molecules containing transition metals are very interesting…
    …but we won't see them in Chem205

CO_2 Carbon dioxide

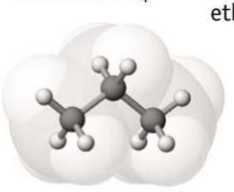
BCl_3 boron trichloride

methane, CH_4

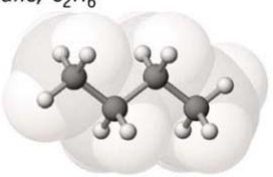


ethane, C_2H_6

Some "hydrocarbons"



propane, C_3H_8



butane, C_4H_{10}

Molecular compounds: Properties (Physical & Chemical)

- Depend on degree of attraction between individual molecules…
  - Compared to electrostatic interactions between ions, intermolecular interactions are quite weak
  - Learn more about this near end of course…& Chem206
- Unlike ionic compounds: highly variable properties
  → gases, liquids, solids…

  More common for larger/heavier molecules
  → because of heavier atoms *and/or* larger # of atoms

- Even though atoms in molecules usually have full valence shell, molecules can still be very reactive!
  - *E.g.,* halogens: F_2, Cl_2… would rather share e⁻s unequally or better yet, not at all (→ions)

Binary *Covalent* Compounds = between 2 nonmetals

NAMING: in order seen in formula

- **1st element:** named first, same as cations
- **2nd element:** named same as anion (… but isn't)

Difference from ionic compound names

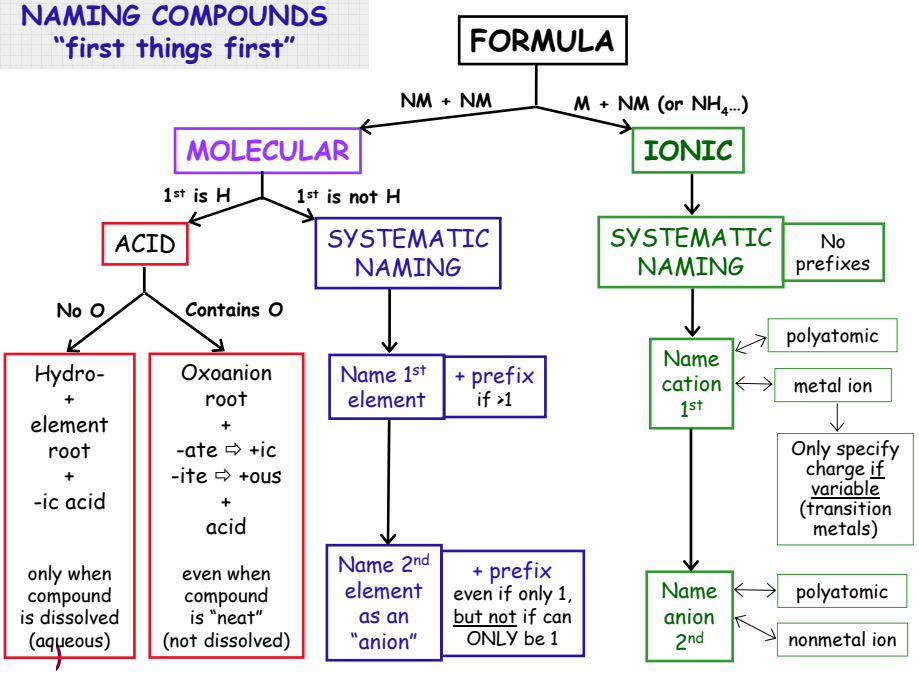
- Can't deduce #s via neutrality (…no ions!)
- Must specify #s of atoms using prefixes
- Exception: don't use mono- for 1st element
  NOR when 1 is the only option

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

*P_2O_5 **di**phosphorus **pent**oxide*
NO_2
CO
HBr hydrogen bromide (= a gas)
H can only form 1 bond ⇨ could only be 1 Br ⇨ omit 'mono'

Note: When hydrogen halide gases are dissolved in water ⇨ ACIDS named as **"hydrohalic acids"** due to striking properties

GENERAL STRATEGY FOR NAMING COMPOUNDS "first things first"



PRACTICE: names & formulae for compounds

IONIC or MOLECULAR?

NAME THESE:

$CaCO_3$	limestone
N_2O	laughing gas
$Fe(OH)_3$	a component of rust
$Ca_3(PO_4)_2$	mineral component of bone
ClO_2	a disinfectant

PROVIDE FORMULAE FOR:

sodium cyanide

xenon hexafluoride

copper(II) nitrate

carbon disulfide

(20)

ASSIGNED READINGS

- BEFORE NEXT CLASS:

  Read rest of Ch. 3

  & work on Ch.3 exercises

- Practice naming/formulae of compounds