

Chapter 2

Atoms, Molecules and Ions

I) Atoms

A) Dalton's Atomic Theory

1) Elements composed of minute, indivisible particles called,

Atoms

2) Atoms of an element are identical & different from atoms of any other elements

- have different properties & different masses

- 3) Atoms combine in whole numbers to form compounds (molecules)

Law of Multiple Proportions

- 4) Compounds are composed of atoms of diff. elements chemically combined.

- relative number of each type of atom is constant

Law of Constant Composition

- 5) In chemical rxn's, atoms are rearranged, but the number & kind of atoms is unchanged

Law of Conservation of Mass

II) Sizes of Atoms

A) Mass

mass of H = 1.67×10^{-24} g

Define atomic mass unit

1 amu = 1.6603×10^{-24} g

Masses of atoms: 1 - 260 amu

B) Radius (Volume)

Atoms pictured as spherical

Radii

$$0.5 \times 10^{-8} \text{ cm} \rightarrow 2.4 \times 10^{-8} \text{ cm}$$

Use nm,

$$0.05 \text{ nm} \rightarrow 0.24 \text{ nm}$$

Also use angstrom, Å

$$1 \text{ Å} = 10^{-10} \text{ m} = 10^{-8} \text{ cm}$$

$$\therefore 0.5 \text{ Å} \rightarrow 2.4 \text{ Å}$$

III) Subatomic Particles

Atom is composed of smaller subatomic particles

Atom: smallest particle of an element that retains properties of that element

A) Electron, e^-

$$\text{charge} = -1.6022 \times 10^{-19} \text{ C} \\ \text{(coulomb)}$$

$$m_{e^-} = 9.1094 \times 10^{-28} \text{ g} \\ = 5.486 \times 10^{-4} \text{ amu}$$

B) Proton, p

Matter is **neutral**:

removal of e^- leaves a **(+)** **charged** particle

remove e^- from **H**
 $\Rightarrow H^+$, a **proton (p)**

- **fundamental** particle

charge = $+ 1.6022 \times 10^{-19} \text{ C}$

$m_p = 1.6726 \times 10^{-24} \text{ g}$

= 1.0073 amu

$m_p \approx 1836 m_{e^-}$

Other atoms contain > 1 p

Number of protons in atom
characteristic of element

Atoms are neutral,

$$\# p = \# e^{-}$$

C) Neutron, n

Only about $\frac{1}{2}$ of mass of atoms
accounted for by protons

charge = 0

$$\begin{aligned} m_n &= 1.6749 \times 10^{-24} \text{ g} \\ &= 1.0088 \text{ amu} \end{aligned}$$

$$m_n \approx m_p$$

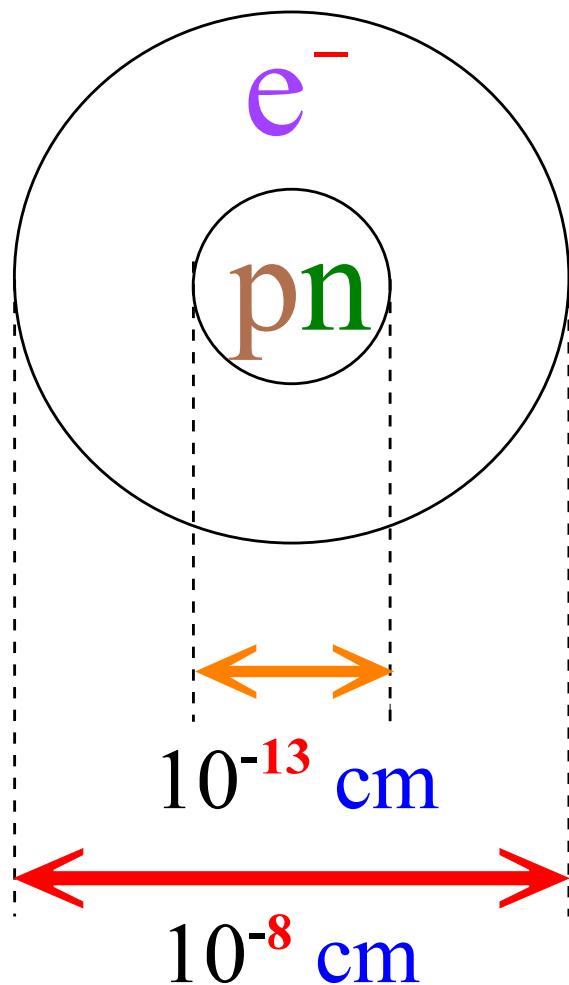
D) Summary of Subatomic Particles

particle	symbol	mass (amu)	relative charge
electron	e^-	0.0005486	-1
proton	p	1.0073	+1
neutron	n	1.0088	0

$$m_n \approx m_p \gg m_{e^-}$$

E) Nuclear Model of the Atom

Atom composed of **dense nucleus**, containing **protons** & **neutrons** & **most** of atom's **mass** surrounded by e^- in **motion** in **mostly empty space**



diameter of atoms **very small**

IV) Composition of Atoms

A) Atomic Number, Z

$Z = \#$ of protons

Distinguishes atoms of **one** element from those of **another**

Whole number in **block** w. **chemical symbol** in P.T.

Elements in P.T. ordered by **inc. atomic no.**

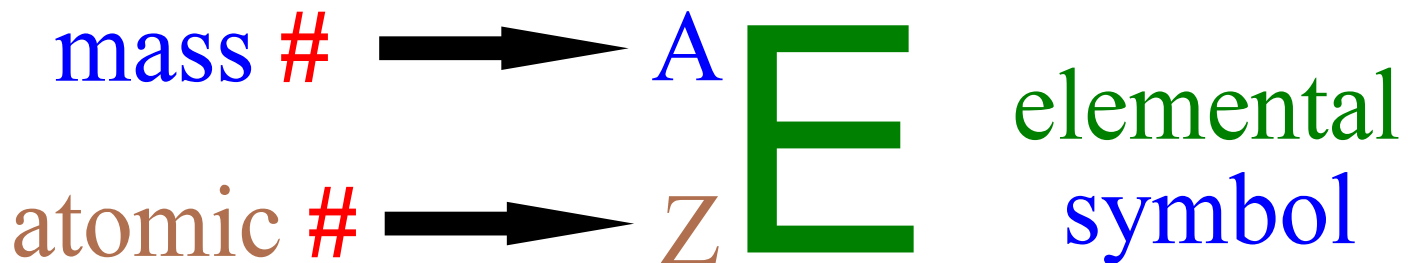
In **neutral** atom, $\# p = \# e^{-}$

B) Mass Number, A

$A = \# p + \# n$

C) Elemental Symbol

Describes composition of nucleus



1) Ex 1: What does the following symbol represent?



Sometimes only show mass #



2) Ex 2:



D) Isotopes

Atoms of **same element** which have **different numbers** of **neutrons**

∴ **same atomic #, Z**
different mass #, A

“A” distinguishes between **isotopes** of the **same element**

Note: **Isotopes** of the **same element** have the **same chemical properties**

1) Ex: Naturally occurring boron consists of 2 isotopes



B) Atomic Weight

A.W. scale based on assignment of exactly 12 amu to $^{12}_6\text{C}$

A.W. is weighted average of naturally occurring isotopes expressed in amu

1) Ex: The two isotopes of silver are ^{107}Ag and ^{109}Ag , having natural abundances of 51.35% and 48.65%, respectively. Their isotopic masses are 106.916 & 108.914 amu, respectively. Determine the A.W. of Ag.

V) Periodic Table

A) Periodic Law

Mendeleev: table based on idea that **properties** of **elements** are **periodic** functions of their **A.W.**

- **exceptions**: **I & Te** ; **Ar & K**

Moseley: proper **correlation** is with **atomic number**

1) Modern Periodic Law

Properties of the **elements** are **periodic** functions of their

Atomic Number

B) Modern Periodic Table

Arrangement of **elements** in order of **inc. atomic no.**, placing those with **similar chem.** and **phys. prop.** in columns.

1) Groups

Vertical **columns** called **groups** or **families**

- **elements** within a **group** have **similar prop.**

Labeled at **top** of **column** by **Roman numerals** (**I - VIII**) or **Arabic numerals** (**1 - 8**) and **letter**, **A** or **B**

a) Representative Elements

(main-group elements)

1 A - 8 A

1) Specific Group Names

1 A alkali metals

2 A alkaline earth metals

7 A halogens

8 A noble or rare gases

b) Transition Metal Elements

1 B - 8 B

- metals

2) Periods

Horizontal rows called periods

Two long rows below main body of table are:

Inner transition elements
- lanthanides & actinides

1 st period	H - He	2 elements
2 nd period	Li - Ne	8 elements
3 rd period	Na - Ar	8 elements
4 th period	K - Kr	18 elements
5 th period	Rb - Xe	18 elements
6 th period	Cs - Rn	32 elements

Metals

solids
(except Hg)

metallic
luster

malleable
& ductile

good conductors
of
heat & electricity

oxides:

nonvolatile

high melting

MgO, Na₂O

Nonmetals

gases or solids
(except Br)

variety of color
& appearance

solids are
brittle

poor conductors
(insulators)

oxides:

volatile

low melting

CO, CO₂, SO₂

VI) Molecular Elements & Compounds

A) Molecular Substances

Group of chemically bonded atoms which has the characteristic properties of the substance

1) Molecular Elements

a) Diatomics

Contain 2 atoms



2 H atoms

bonded together



other diatomic elements

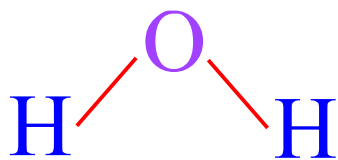


b) Polyatomics



2) Molecular Compounds

Molecules of compounds contain
2 or more diff. elements



2 H atoms &
1 O atom



carbon dioxide

1 C atom &
2 O atoms

3) Molecular Formula

Actual number of each kind of atom in a molecule

C_6H_6 Benzene

C_2H_5OH Ethanol

4) Empirical Formula

Relative number of atoms of each kind in a molecule

- smallest whole-number ratio of atoms

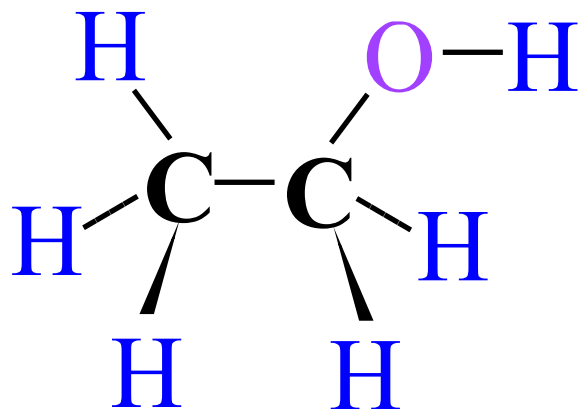
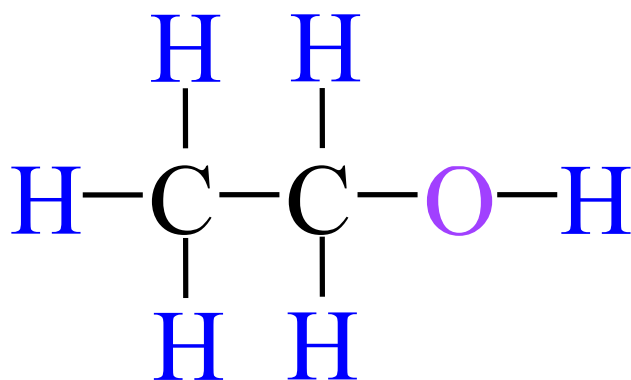
C_1H_1 Benzene or acetylene

Subscripts in a molecular formula are always some integer multiple of subscripts in empirical formula

5) Structural Formula

Gives an idea about the **structure** of the **molecule**

Ethanol



VII) Ionic Substances

A) Ions

particle that contains **more**
or **fewer** e^- than **protons**

\therefore Has **NET** electrical charge

$$\text{Total charge} = \# p - \# e^-$$

1) Anion

Negative ion resulting from **gain** of
1 or **more** e^- by neutral atom

a) Ex:



Br^- has **1** extra e^- than Br

(**# p** does **NOT** change)

b) Ex:



* Formation of **anions** is a property of **nonmetals**

2) Cation

Positive ion resulting from **loss** of **1** or **more** e^{-} by neutral atom

a) Ex:



* Formation of **cations** is a property of **metals**

3) Predicting Charge Using P.T.

Representative Elements

I A – VIII A

gain or lose e^- to achieve same
e^- as nearest noble gas

Br^- 36 e^- \Rightarrow Kr

S^{2-} , Cl^- , K^+ , Ca^{2+} 18 e^- \Rightarrow Ar

isoelectronic series

(same # e^-)

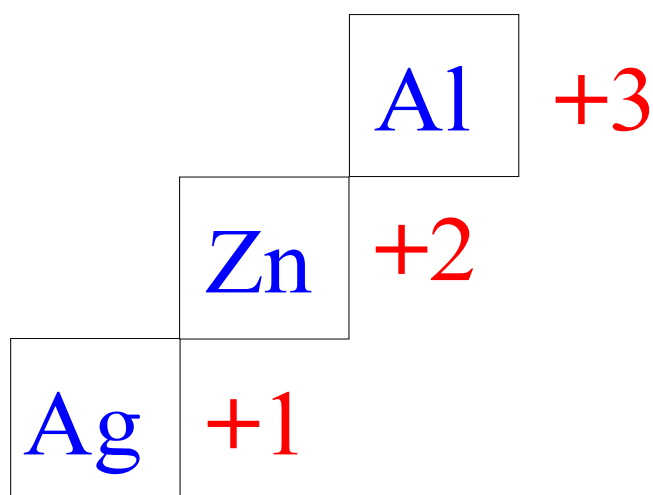
a) Cation Groups

charge = group #

I A = + 1 Li⁺

II A = + 2 Mg²⁺

a) Special Cations



2) Anion Groups

charge = group # - 8

V A = - 3 N³⁻

VI A = - 2 O²⁻

VII A = - 1 F⁻

	IA	IIA	IIIB	IVB	VB	VIB	VIIIB	VIIIIB					IB	IIB	IIIA	IVA	VA	VIA	VIIA	VIIIA
1	1.008 H 1																		4.003 He 2	
2	6.941 Li 3	9.012 Be 4												10.81 B 5	12.011 C 6	14.007 N 7	15.999 O 8	18.998 F 9	20.179 Ne 10	
3	22.990 Na 11	24.305 Mg 12												26.98 Al 13	28.09 Si 14	30.974 P 15	32.06 S 16	35.453 Cl 17	39.948 Ar 18	
4	39.098 K 19	40.08 Ca 20	44.96 Sc 21	47.88 Ti 22	50.94 V 23	52.00 Cr 24	54.94 Mn 25	55.85 Fe 26	58.93 Co 27	58.69 Ni 28	63.546 Cu 29	65.38 Zn 30	69.72 Ga 31	72.59 Ge 32	74.92 As 33	78.96 Se 34	79.904 Br 35	83.80 Kr 36		
5	85.47 Rb 37	87.62 Sr 38	88.91 Y 39	81.22 Zr 40	92.91 Nb 41	95.94 Mo 42	98 Tc 43	101.07 Ru 44	102.91 Rh 45	106.42 Pd 46	107.87 Ag 47	112.41 Cd 48	114.82 In 49	118.69 Sn 50	121.75 Sb 51	127.60 Te 52	126.90 I 53	131.39 Xe 54		
6	132.91 Cs 55	137.33 Ba 56	138.91 La 57	178.39 Hf 72	180.95 Ta 73	183.85 W 74	186.21 Re 75	190.23 Os 76	192.22 Ir 77	195.08 Pt 78	196.97 Au 79	200.59 Hg 80	204.38 Tl 81	207.2 Pb 82	208.98 Bi 83	209 Po 84	210 At 85	222 Rn 86		
7	223 Fr 87	226.03 Ra 88	227.03 Ac 89	261 Rf 104	262 Ha 105	263 Sg 106	262 Ns 107	265 Hs 108	266 Mt 109	269 Uu 110	272 Uub 111	277 Uuq 112								

6	Lanthanide Series	140.12 Ce 58	140.91 Pr 59	144.24 Nd 60	145 Pm 61	150.36 Sm 62	151.96 Eu 63	157.25 Gd 64	158.93 Tb 65	162.50 Dy 66	164.93 Ho 67	167.26 Er 68	168.93 Tm 69	173.04 Yb 70	173.04 Lu 71
7	Actinide Series	232.04 Th 90	231.04 Pa 91	238.03 U 92	237.05 Np 93	Pu 94	Am 95	Cm 96	Bk 97	Cf 98	Es 99	Fm 100	Md 101	No 102	Lr 103

A PERIODIC CHART OF THE ELEMENTS
(Based on ¹²C)

B) Ionic Compounds

Oppositely charged ions held together
by electrostatic attractions

Combinations of metals & nonmetals

Crystalline solids (salts)

1) Formula Units

Compounds are electrically neutral

total (+) chg = total (-) chg

NaCl neutral
(cation)(anion)

Formula shows **simplest**
ratio of **ions**

- **empirical formula**

NOT a molecule

3-D arrangement of **ions**

a) Ex : Cmpd. formed from
 Ca^{2+} & CO_3^{2-}

Ca CO_3
cation anion

VIII) Naming Ions

A) Monatomic Ions

1) Cations

Use **name** of **element**
followed by “**ion**”

K^+ potassium ion

Zn^{2+} zinc ion

2) Anions

Add “**ide**” to **root** of **element's** name

Br^- bromide ion

S^{2-} sulfide ion

B) Stock System & Older System

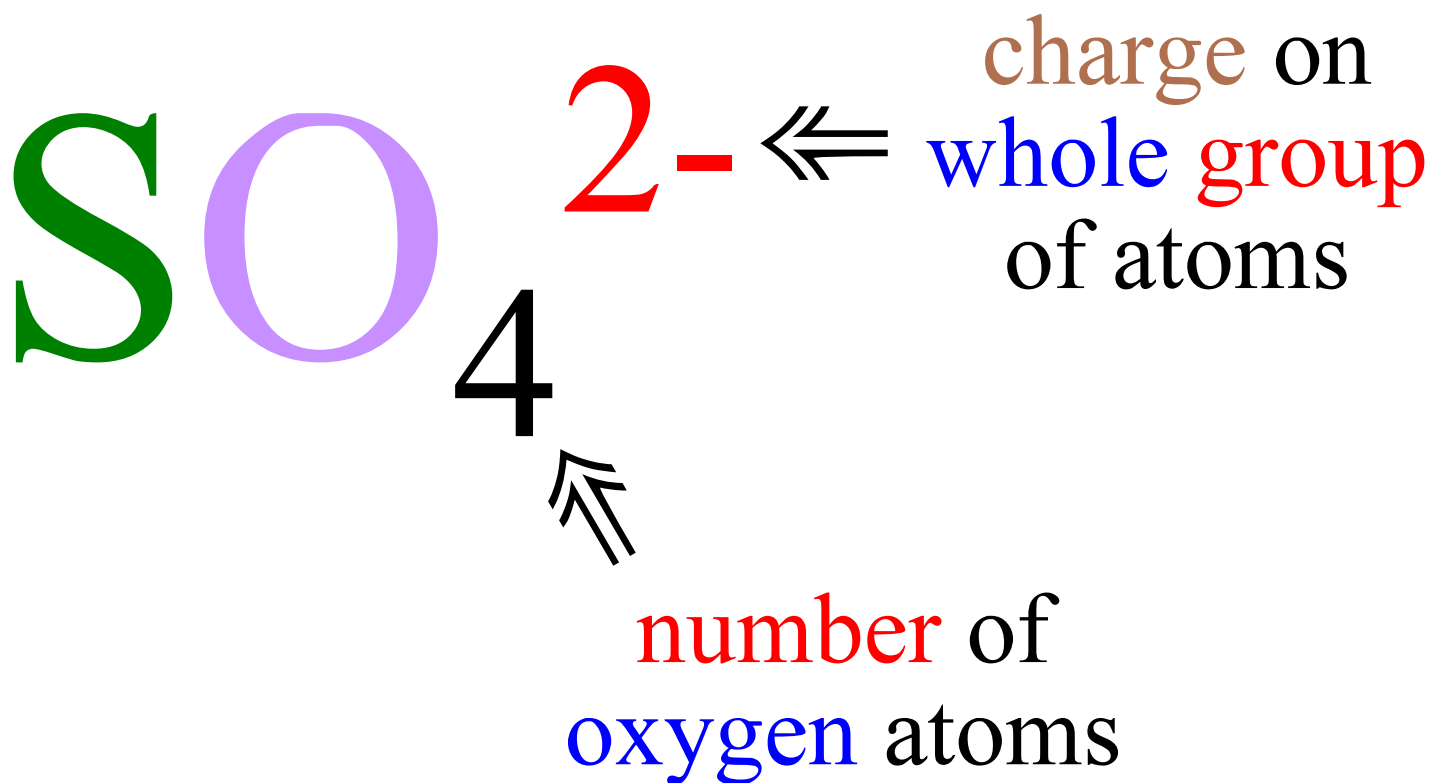
Many metals have more than one possible charge

- transition metals
- representative metals

	<u>Stock</u>	<u>Older</u>
Fe^{2+}	iron (II)	ferrous
Fe^{3+}	iron (III)	ferric
Cu^{+}	copper (I)	cuprous
Cu^{2+}	copper (II)	cupric
Sn^{2+}	tin (II)	stannous
Sn^{4+}	tin (IV)	stannic

C) Polyatomic Ions

Group of chemically bonded atoms with an overall charge



1) Polyatomic Anions ending in -ide

OH^- hydroxide ion

CN^- cyanide ion

2) Polyatomic Cations

NH_4^+ ammonium ion

H_3O^+ hydronium ion

Hg_2^{2+} mercury (I) ion

3) Misc. Polyatomic Anions

MnO_4^- permanganate ion

$\text{C}_2\text{H}_3\text{O}_2^-$ acetate ion

CrO_4^{2-} chromate ion

$\text{Cr}_2\text{O}_7^{2-}$ dichromate ion

4) Polyatomic Anions - Oxyanions

Carbonate



Chlorate



Nitrate



Phosphate



Sulfate



a) Vary Number of Oxygens

Prefixes & suffixes indicate changes made to base anion.

1) Suffixes

-ate base anion

-ite 1 less O-atom
than -ate

Nitrite NO_2^-

2) Prefixes

per- (over) 1 more O-atom
than -ate

hypo- (under) 1 less O-atom
than -ite

3) Ex 1:

ClO_4^-	perchlorate
ClO_3^-	chlorate
ClO_2^-	chlorite
ClO^-	hypochlorite
Cl^-	chloride

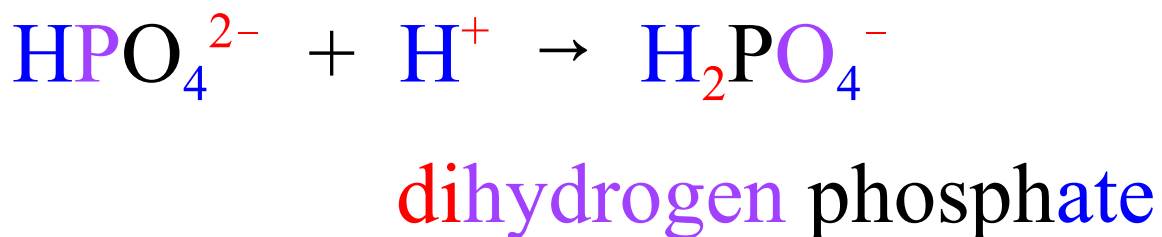
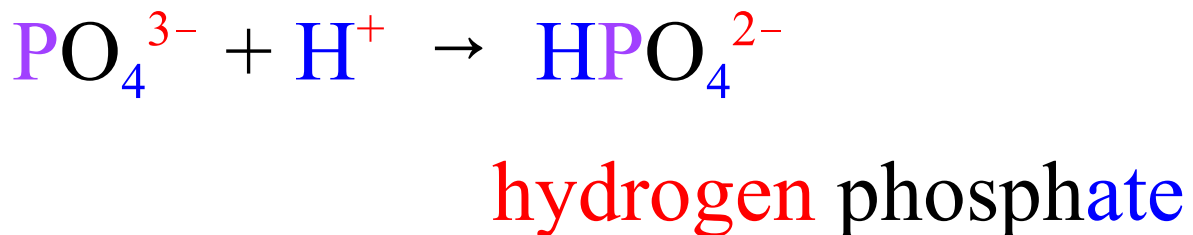
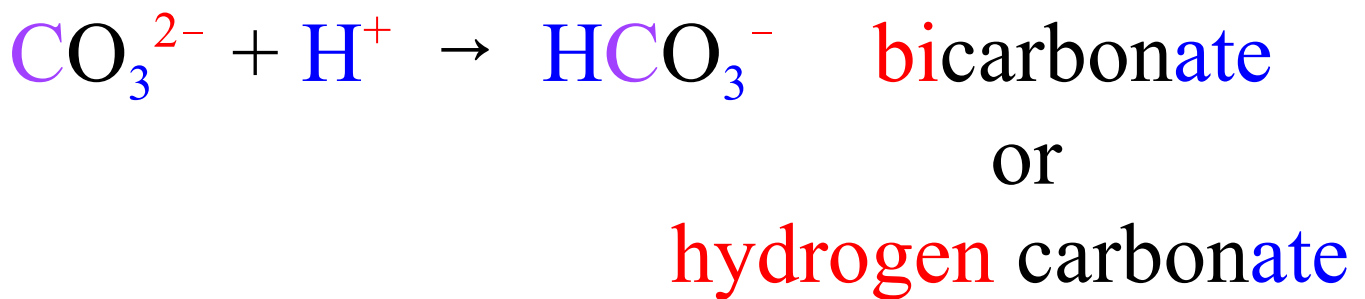
4) Ex 2: What is bromate, perbromate, hypoiodite?

5) Ex 3: What is SO_3^{2-} ?

Note: Overall charge on the “family” of anions remains same

b) Addition of H⁺ to
-2 or -3 Oxyanion

Resulting species **still charged**
- **anions**

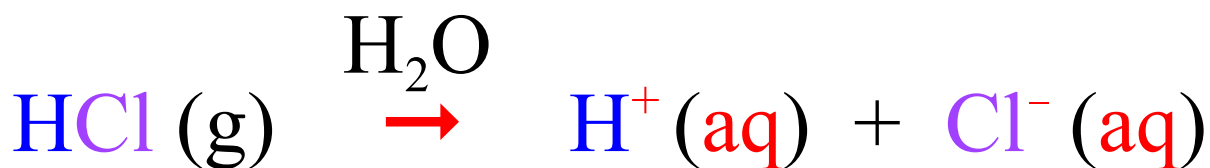


c) Acids

H^+ combines with **anion** to produce a **neutral** compound \Rightarrow

Acid

Not ionic but **ionize** in H_2O to produce H^+ (H_3O^+)



1) Binary Acids

Hydrogen + **nonmetal**

-ide \Rightarrow **-ic acid**

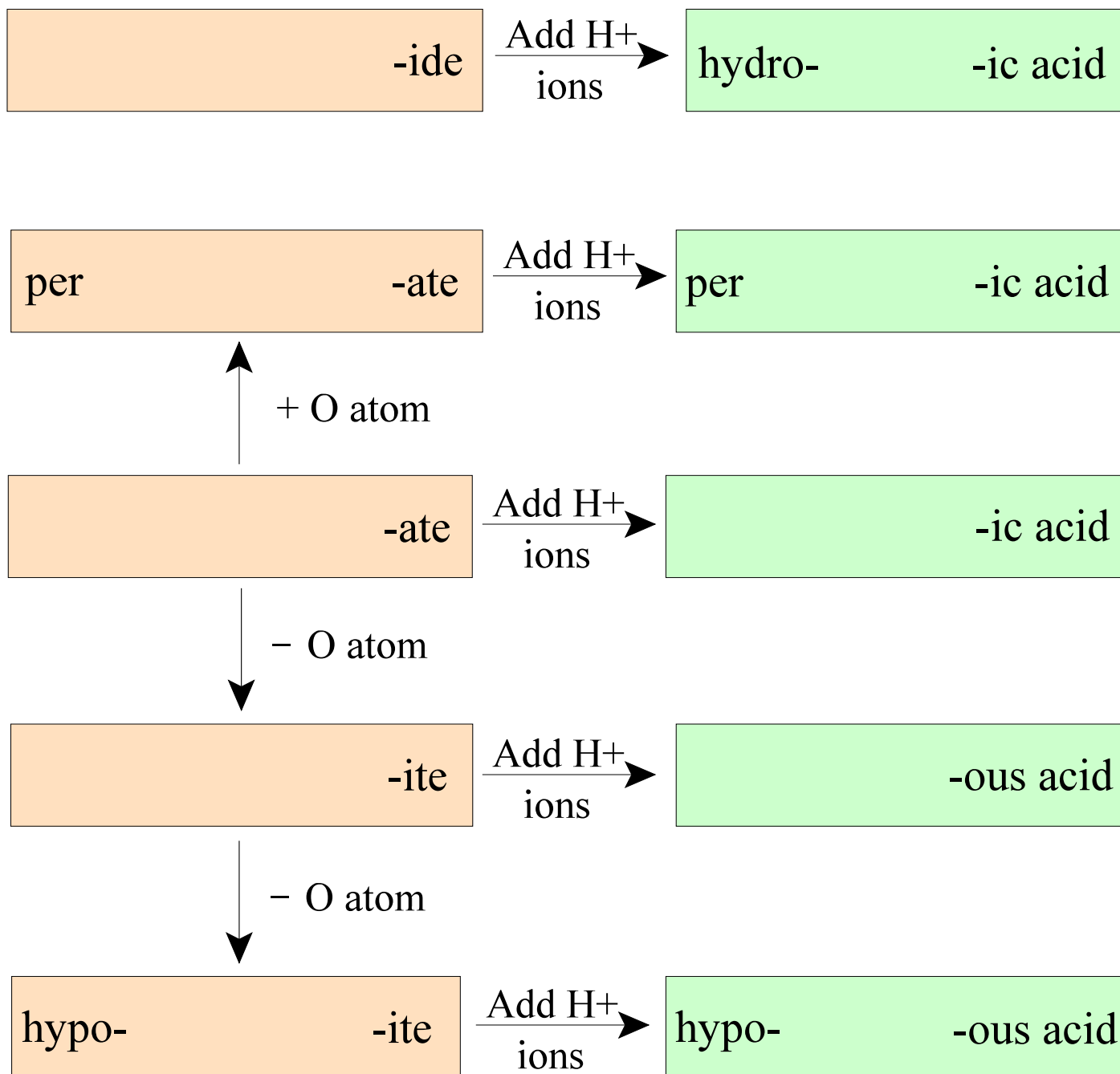
Precede name with **hydro-**

$HF(aq)$ **hydrofluoric acid**

Summary of Acid/Anion Naming

Anion

Acid



IX) Formulas & Names of Ionic Compounds

1) Ex 1: What compound is formed from Ca^{2+} and CO_3^{2-} ?

2) Ex 2: NH_4^+ and S^{2-}

3) Ex 3: Al^{3+} and SO_4^{2-}

4) Ex 4: Sn^{4+} and O^{2-}

5) Ex 5: Write the formula for manganese (IV) oxide.

6) Ex 6: Write the formula for iron(II) sulfite.

X) Binary Molecular Compounds

2 diff. elements

nonmetals

or

nonmetals & semimetals

Usually, element further to left & lower in column in PT (less electronegative) given first

B	Si,C	As,P,N	H	Se,S	I,Br,Cl	O	F
3A	4A	5A	*	6A	7A	*	7A

SiC silicon carbide

NO nitrogen monoxide

H₂S hydrogen sulfide

A) Same Element; Multiple Compounds

Greek prefix indicates number
of atoms of each element

