Multivalent Ions

- Some elements can form more than one ion
- There are 2 systems in use to name these ions

IUPAC – International Union of Pure & Applied Chemists

Ion	Stock Name (old method)	IUPAC Name (new method)
Fe^{2+}	Ferrous	Iron (II)
Fe^{3+}	Ferric	Iron (III)
Cu^{1+}	Cuprous	Copper (I)
Cu^{2+}	Cupric	Copper (II)
Zn^{2+}	----------	Zinc
Ag^{+}	----------	Silver
Co^{2+}	Cobaltous	Cobalt (II)
Co^{3+}	Cobaltic	Cobalt (III)
As^{3+}	Arsenious	Arsenic (III)
As^{5+}	Arsenic	Arsenic (V)
Cd^{2+}	----------	Cadmium
Sn^{2+}	Stannous	Tin (II)
Sn^{4+}	Stannic	Tin (IV)
Sb^{3+}	Antimonous	Antimony (III)
Sb^{5+}	Antimonic	Antimony (V)
Au^{1+}	Aurous	Gold (I)
Au^{3+}	Auric	Gold (III)
Hg^{1+}	Mercurous	Mercury (I)
Hg^{2+}	Mercuric	Mercury (II)
Pb^{2+}	Plumbous	Lead (II)
Pb^{4+}	Plumbic	Lead (IV)

Note: The ion with the lower valence has an "ous" suffix and the higher one has an "ic" suffix.

<u>Multivalent Ioinc Bonding</u>

- Same rules apply as in ionic bonding
- Only this time the old **stock name** may be used and if the **IUPAC** system is used, the charge on the metallic ion must be shown in <u>roman numerals</u>.
- The numbers in roman numerals refers to the charge on the metallic ions

Example:

1. SnF_2 = stannous fluoride *or* tin (II) fluoride
2. Gold (III) Oxide = $Au^{3+}\ O^{2-}$ = Au_2O_3
3. Lead (IV) Oxide = $Pb^{4+}\ O^{2-}$ = Pb_2O_4 = PbO_2 (*reduce*)

Example 1)

Write the chemical name for BeH_2

Solution 1)

1. Write the names of the cation and the anion. The anion must end in the suffix "-ide"

   beryllium hydride

2. Since beryllium has a fixed valence, we are finished.

Example 2)

Write the chemical name for FeS

Solution 2)

1. Write the names of the cation and the anion. The anion must end in the suffix "-ide"

   iron sulfide

2. Since iron has more than one valence, use the subscripts to determine the charges on the ions.

   Fe^{1+} S^{1-} *but the charge on S is 2-!*
   Fe^{2+} S^{2-} *iron (II) sulfide*

Give the correct formula:

Chemical Name	**Ions Formed**	**Chemical Formula**
Cobalt (II) chloride	Co^{2+} Cl^{1-}	$CoCl_2$
Tin (IV) nitride		
Zinc iodide		
Plumbous chloride		
Silver Bromide		
Antimony (III) phosphide		
Mercuric oxide		
Cupric bromide		
Ferric sulphide		
Mercurous iodide		

Name the following compounds:

Chemical Name	**IUPAC Name**	**Stock Name**
CuO	Copper (II) Oxide	Cupric Oxide
SnF_4		
$PbCl_4$		
$AsCl_5$		
AgBr		
CdI_2		
ZnO		
Sb_2O_3		
Fe_2O_3		
$AuBr_3$		

Write the chemical formula for the following binary ionic compounds:

a) Calcium chloride
b) Potassium oxide
c) Lithium nitride
d) Cadmium oxide
e) Silver chloride
f) Mercury (I) sulfide
g) Barium fluoride
h) Sodium bromide
i) Zinc iodide
j) Copper (II) chloride
k) Gold (I) iodide
l) Nickel (II) sulfide
m) Aluminum hydride
n) Iron (III) chloride
o) Potassium nitride
p) Magnesium nitride
q) Tin (IV) fluoride
r) Iron (III) sulfide
s) Cobalt (II) bromide
t) Manganese (II) sulfide
u) Lead (IV) oxide
v) Cadmium chloride
w) Strontium oxide
x) Chromium (II) fluoride
y) Lithium sulfide
z) Silver oxide

Give the chemical name for the following binary ionic compounds. Include both the IUPAC and stock names, where applicable.

a) FeS
b) $CrCl_3$
c) MgO
d) $AlCl_3$
e) LiF
f) K_2S
g) $ZnBr_2$
h) FeO
i) Fe_2O_3
j) NiF_2
k) CuS
l) Hg_2O
m) AlN
n) $BaBr_2$
o) Ag_2S
p) $BiCl_3$
q) SnO
r) CdS
s) MnO_2
t) SrH_2
u) AuF
v) UF_4
w) Co_2O_3
x) K_3N
y) PbI_2
z) SnO_2

Polyatomic Anions (Negative Ions)

Polyatomic ions consist of **groups of atoms** that carry an overall negative charge. Since these are very common and have their own special name, you are required to learn them. Treat polyatomic ions as a "package deal".

-1	-2	-3
$C_2H_3O_2^-$ Acetate CH_3COO^-	CO_3^{2-} Carbonate	PO_4^{3-} Phosphate
ClO_3^- Chlorate	SO_4^{2-} Sulphate	
BrO_3^- Bromate	CrO_4^{2-} Chromate	
IO_3^- Iodate	$C_2O_4^{2-}$ Oxalate	
HCO_3^- Bicarbonate	$Cr_2O_7^{2-}$ Dichromate	
NO_3^- Nitrate		
MnO_4^- Permanganate		
SCN^- Thiocyanate		
CN^- Cyanide		
OH^- Hydroxide		
HSO_4^- Hydrogen Sulphate		
HCO_3^- Hydrogen Carbonate		
HS^- Hydrogen Sulfide		

Complex Oxyanions: contain oxygen

There is only one **polyatomic cation** (positive polyatomic ion)

Ammonium NH_4^+

Not to be confused with **Ammonia NH_3**

Sample Problems:

Name	Ions	Chemical Formula
Sodium Carbonate	Na^{1+} CO_3^{2-}	Na_2CO_3
Copper (II) Sulphate	Cu^{2+} SO_4^{2-}	$CuSO_4$
Copper (II) Bromate	Cu^{2+} BrO_3^{-}	$Cu(BrO_3)_2$

******ENCLOSE THE ENTIRE POLYATOMIC ION IN BRACKETS WHEN THE SUBSCRIPT IS GREATER THAN 1**

Polyatomic Ions

Name	Ions	Chemical Formula
Silver acetate		
	K^{+} MnO_4^{-}	
Tin (II) dichromate		
Zinc hydroxide		
		MgC_2O_4
Barium oxalate		
		$Al(C_2H_3O_2)_3$
		$Cu(OH)_2$
Cupric nitrate		
Lead (II) sulphate		
	Pb^{2+} NO_3^{-}	
		Hg_3PO_4
	K^{+} SCN^{-}	
		$Na_2C_2O_4$
Gold (III) cyanide		

	Na^{+} MnO_4^{-}	
Mercury (II) nitrate		
Chromium (III) oxalte		
Cobalt (II) acetate		
Ammonium dichromate		
	Ba^{2+} CO_3^{2-}	
	Pb^{4+} SO_4^{-2}	
Potassium bicarbonate		
Copper (II) sulphate		
Calcium carbonate		
		$FeSO_4$
Copper (II) nitrate		
	Na^{+} HCO_3^{-}	
Ferrous phosphate		
Sodium thiocyanate		
	Li^{+} SO_4^{2-}	
Ammonium phophate		
		$CaSO_4$
	Na^{+} OH^{-}	
Stannous dichromate		
Plumbous acetate		
	Hg^{2+} PO_4^{3-}	
Ammonium oxalte		
		$Fe(OH)_3$
		$MgCO_3$

Nomenclature for Oxyanions

O's	Formula	Name	Style
One more	ClO_4^-	**Per**chlorate	Per……..ate
----------	ClO_3^-	Chlor**ate**	……ate
One fewer	ClO_2^-	Chlor**ite**	……ite
Two fewer	ClO^-	**Hypo**chlor**ite**	Hypo……ite

Example:

IO_2^- **Iodate** (parent name) becomes **Iodite** (*one fewer oxygen*)

KNO_2 Potassium Nitrite

Chemical Equation	Name
SO_3^{2-}	
BrO_3^-	
BrO_2^-	
BrO^-	
IO_4^-	
IO_3^-	
IO_2^{--}	

Practice Problems

Chemical Equation	Name
Na_2CO_3	
$Pb(NO_3)_4$	
$Sn(ClO)_2$	
Ag_2SO_3	
$Mg_3(PO_2)_2$	
$Ca(NO_2)_2$	
$AlPO_4$	
KIO	
$Zn(BrO_4)_2$	
CuClO	
	Mercuric periodate
	Calcium hypobromite
	Potassium sulfite
	Nickel (II) chlorite
	Aluminum carbonate
	Stannous periodate
	Gold (III) bromate
	Copper (II) sulphate
	Sodium nitrite
	Lead (IV) periodate

Oxy-acids

Oxy – meaning they contain oxygen **Acid** – meaning they contain hydrogen

Naming:
All oxy-acids get their name logically from their parent oxyanions by changing the ending from **"-ate"** to **"-ic acid"**

-ic Acids

H	**H_2**	**H_3**
$HClO_3$ Chlor**ic** Acid	H_2SO_4 Sulphur**ic** Acid	H_3PO_4 Phosphor**ic** Acid
$HBrO_3$ Brom**ic** Acid	H_2CO_3 Carbon**ic** Acid	
HNO_3 Nitr**ic** Acid		
HIO_3 Iod**ic** Acid		

-ous Acids *Oxyacids with one less oxygen than their parents*

H	**H_2**	**H_3**
$HClO_2$ Chlor**ous** Acid	H_2SO_3 Sulphur**ous** Acid	H_3PO_3 Phosphor**ous** Acid
$HBrO_2$ Brom**ous** Acid	----------	
HNO_2 Nitr**ous** Acid		
HIO_2 Iod**ous** Acid		

-ous Acids *Oxyacids with two less oxygen than their parents*

H	**H_2**	**H_3**
HClO **Hypo**chlor**ous** Acid	----------	H_3PO_2 **Hypo**phosphor**ous** Acid
HBrO **Hypo**brom**ous** Acid	----------	

HIO **Hypo**iod**ous** Acid		

Per---ic Acids *Oxyacids with one more oxygen than their parents*

H	**H_2**	**H_3**
$HClO_4$ **Per**chlor**ic** Acid	----------	----------
$HBrO_4$ **Per**brom**ic** Acid	----------	

HIO_4 **Per**iod**ic** Acid		

Binary Acids

The following is a list of common binary acids that must me memorized:

Name	Formula
Hydrochloric acid *or* hydrogen chloride	HCl
Hydrofluoric acid *or* hydrogen fluoride	HF
Hydroiodic acid *or* hydrogen iodide	HI
Hydrobromic acid *or* hydrogen bromide	HBr
Hydrosulfuric acid *or* hydrogen sulfide	H_2S
Hydroselenic acid *or* hydrogen selenide	H_2Se

Note – these do not contain oxygen

Practice Problems

Chemical Equation	Name
HCl	
H_2SO_4	
HNO_2	
HBr	
$HClO_4$	
H_2Se	
$HBrO_3$	
H_2CO_3	
H_3PO_4	
HlO	
$HC_2H_3O_2$	
	Hydrofluoric acid
	Phosphorus acid
	Chlorous acid
	Nitric acid
	Hydrobromic acid
	Hydroiodic acid
	Hydrosulphuric acid
	Sulphurous acid
	Iodous acid
	Periodic acid
	Nitrous acid
	Carbonic acid