Polyatomic compounds are chemical compounds that contain more than two different elements in their formula (i.e., sulfuric acid = H_2SO_4). Also, polyatomic compounds usually contain at least one **polyatomic ion** (i.e., 2 hydrogen ions ($2H^{+1}$) and a sulfate ion (SO_4^{-2}) = sulfuric acid (H_2SO_4)). In this example, sulfate (SO_4^{-2}) is the polyatomic ion. Polyatomic compounds may also contain 2 polyatomic ions (i.e., ammonium (NH_4^{+1}) and hydroxide (OH^{-1}) = ammonium hydroxide (NH_4OH)). Remember, the positive ion (cation) or negative ion (anion), or both, contain two or more different elements in their formula.
Writing a formula for a polyatomic compound follows **exactly the same rules** as we used in Part 1. That is, polyatomic chemical compounds are **neutral**, having a charge of zero (i.e., the combination of charges on the cation(s) and anion(s) must add to zero).
The naming of polyatomic compounds is **similar** to naming binary compounds but some memorization is required initially. Many polyatomic ions are derived from oxygen-containing acids or "**oxy-acids**". The names and formulas of these oxy acids and their derivatives is your starting point for Part 2 of this independent study.

I. OXY ACIDS

An **oxy acid** is a polyatomic compound containing hydrogen, oxygen and an electronegative element (i.e., Cl, N, S, P, etc.). These acids are sometimes referred to as "mother acids" because many other chemical compounds are derived from them. Therefore, the **names and formulas** of related oxy acids and polyatomic ions are derived from them. The top 5 oxy acids are the main oxy acids used in industry. Use the names already given to help fill in the chart below.

oxy acid chemical name	oxy acid chemical formula
phosphoric acid	H_3PO_4
sulfuric acid	H_2SO_4
carbonic acid	H_2CO_3
nitric acid	HNO_3
chloric acid	$HClO_3$
fluoric acid	HFO_3
bromic acid	$HBrO_3$
iodic acid	HIO_3

J. OXY ACIDS DERIVATIVES

An **oxy acid derivative** may be formed during a chemical reaction when oxygen atom(s) are added to or removed from an **oxy acid**. (**Note:** Although you can write the chemical formulas and names of all oxy acid derivatives using the system described below, some may not exist naturally or be able to be synthetically produced.)

NAMING and WRITING FORMULAS for OXY ACID DERIVATIVES:

Information in the box below shows how the name and formula of an oxy acid are changed when adding or removing oxygen atoms from the original **oxy acid** formula.

+ if **ONE OXYGEN ATOM IS ADDED**, add prefix "per" to the "ic" acid name
= **per**sulfuric acid (called "per-ic" acid)

+ **OXY ACID** = sulfuric acid (called "ic" acid, AKA Amother acid@)

+ if **ONE OXYGEN ATOM IS REMOVED**, remove "ic" and add "ous" to acid name
= sulfur**ous** acid (called "ous" acid)

+ if **TWO OXYGEN ATOMS ARE REMOVED**, add prefix "hypo" to "ous" acid name =
hyposulfurous acid (called "hypo-ous" acid)

Complete the following table to show how you would name and write the formulas for the oxy acid derivatives of sulfuric acid (use information from the box above).

change in oxy acid formula	oxy acid name	oxy acid formula
add one oxygen atom(*) ("per-ic" acid)	persulfuric acid	H_2SO_5
no change ("ic" acid)	sulfuric acid	H_2SO_4
remove one oxygen atom(*) ("ous" acid)	sulfurous acid	H_2SO_3
remove two oxygen atoms(*) ("hypo-ous" acid)	hyposulfurous acid	H_2SO_2

(*) These are the **derivatives** of the original **oxy acid**. Since the derivatives contain oxygen and are acids (like the original oxy acid), they are also referred to as oxy acids.

OTHER OXY ACID DERIVATIVES

Complete a similar table for each of the other four main oxy acids:

a) H_3PO_4 b) H_2CO_3 c) HNO_3 d) $HClO_3$

change in oxy acid formula	oxy acid name	oxy acid formula
add one oxygen atom ("per-ic" acid)	perphosphoric acid	H_3PO_5
no change ("ic" acid)	phosphoric acid	H_3PO_4
remove one oxygen atom ("ous" acid)	phosphorous acid	H_3PO_3
remove two oxygen atoms ("hypo-ous" acid)	hypophosphorous acid	H_3PO_2

change in oxy acid formula	oxy acid name	oxy acid formula
add one oxygen atom ("per-ic" acid)	percarbonic acid	H_2CO_4
no change ("ic" acid)	carbonic acid	H_2CO_3
remove one oxygen atom ("ous" acid)	carbonous acid	H_2CO_2
remove two oxygen atoms ("hypo-ous" acid)	hypocarbonous acid	H_2CO

change in oxy acid formula	oxy acid name	oxy acid formula
add one oxygen atom ("per-ic" acid)	pernitric acid	HNO_4
no change ("ic" acid)	nitric acid	HNO_3
remove one oxygen atom ("ous" acid)	nitrous acid	HNO_2
remove two oxygen atoms ("hypo-ous" acid)	hyponitrous acid	HNO

change in oxy acid formula	oxy acid name	oxy acid formula
add one oxygen atom ("per-ic" acid)	perchloric acid	$HClO_4$
no change ("ic" acid)	chloric acid	$HClO_3$
remove one oxygen atom ("ous" acid)	chlorous acid	$HClO_2$
remove two oxygen atoms ("hypo-ous" acid)	hypochlorous acid	HClO

Worksheet IJ

Complete the following table in order to practice the naming and formula writing for oxy acids and their derivatives.

chemical name	chemical formula	chemical name	chemical formula
sulfurous acid	H_2SO_3	persulfuric acid	H_2SO_5
fluoric acid	HFO_3	fluorous acid	HFO_2
hypophosphorous acid	H_3PO_2	perphosphoric acid	H_3PO_5
percarbonic acid	H_2CO_4	carbonic acid	H_2CO_3
pernitric acid	HNO_4	hyponitrous acid	HNO
bromous acid	$HBrO_2$	perbromic acid	$HBrO_4$
hypoiodous acid	HIO	iodic acid	HIO_3
perfluoric acid	HFO_4	hyposulfurous acid	H_2SO_2
phosphoric acid	H_3PO_4	hypochlorous acid	HClO
carbonic acid	H_2CO_3	nitrous acid	HNO_2
nitrous acid	HNO_2	percarbonic acid	H_2CO_4
hypochlorous acid	HClO	phosphoric acid	H_3PO_4

Oxy acids and their derivatives dissociate (separate from) their positive hydrogen ions, forming negative polyatomic anions. These negative ions are commonly found combined with **positive metal ions**. This combination of a **metal cation** and a **polyatomic anion** is called a "**salt**". Some of the names of the polyatomic anions which are derived from the oxy acids are given below. Writing the formula of salts that contain these polyatomic anions follows the same rules you have used in the past (i.e., the chemical compound formed is neutral). The names of the chemical compounds are determined by placing the cation name in front of the polyatomic anion name. Use the examples in the right column as a guide. (**Note:** The Aic@ acid always results in the Aate@ anion!)

K. POLYATOMIC ANIONS from "ic" acids

"ic" acid name and formula	polyatomic anion chemical formula	polyatomic anion chemical name	example of chemical name and formula for sodium salt
phosphoric acid H_3PO_4	PO_4^{-3}	phosphate	sodium phosphate Na_3PO_4
sulfuric acid H_2SO_4	SO_4^{-2}	sulfate	sodium sulfate Na_2SO_4
carbonic acid H_2CO_3	CO_3^{-2}	carbonate	sodium carbonate Na_2CO_3
nitric acid HNO_3	NO_3^{-1}	nitrate	sodium nitrate $NaNO_3$
chloric acid $HClO_3$	ClO_3^{-1}	chlorate	sodium chlorate $NaClO_3$
fluoric acid HFO_3	FO_3^{-1}	fluorate	sodium fluorate $NaFO_3$
bromic acid $HBrO_3$	BrO_3^{-1}	bromate	sodium bromate $NaBrO_3$
iodic acid HIO_3	IO_3^{-1}	iodate	sodium iodate $NaIO_3$

L1. POLYATOMIC ANIONS from OXY ACID DERIVATIVES

The following chart shows how you would name the **polyatomic anions** from sulfuric acid and its oxy acid derivatives.

oxy acid	polyatomic anion formula	polyatomic anion name	example of sodium salt
persulfuric acid H_2SO_5	SO_5^{-2}	persulfate **(Aic@ acids always result in Aate@ ions)**	sodium persulfate Na_2SO_5
sulfuric acid H_2SO_4	**SO_4^{-2}**	**sulfate (Aic@ acids always result in Aate@ ions)**	**sodium sulfate Na_2SO_4**
sulfurous acid H_2SO_3	SO_3^{-2}	sulfite **(Aous@ acids always result in Aite@ ions)**	sodium sulfite Na_2SO_3
hyposulfurous acid H_2SO_2	SO_2^{-2}	hyposulfite **(Aous@ acids always result in Aite@ ions)**	sodium hyposulfite Na_2SO_2

Practice Problems:

Note: When writing the chemical formulas for the examples below, if more than one polyatomic ion is required in the chemical formula, **brackets** must be placed around the polyatomic ion.

chemical name	chemical formula	chemical name	chemical formula
potassium persulfate	K_2SO_5	radium sulfate	$RaSO_4$
aluminum sulfate	$Al_2(SO_4)_3$	boron persulfate	$B_2(SO_5)_3$
copper(I) sulfite	Cu_2SO_3	copper(II) hyposulfite	$CuSO_2$
ferrous hyposulfite	$FeSO_2$	iron(III) sulfite	$Fe_2(SO_3)_3$
nickel(III) persulfate	$Ni_2(SO_5)_3$	nickel(II) hyposulfite	$NiSO_2$

L2. POLYATOMIC ANIONS from OXY ACID DERIVATIVES

The following chart shows how you would name the polyatomic anions from phosphoric acid and its oxy acid derivatives.

oxy acid	polyatomic anion formula	polyatomic anion name	example of sodium salt
perphosphoric acid H_3PO_5	PO_5^{-3}	perphosphate	sodium perphosphate Na_3PO_5
phosphoric acid H_3PO_4	**PO_4^{-3}**	**phosphate**	**sodium phosphate Na_3PO_4**
phosphorous acid H_3PO_3	PO_3^{-3}	phosphite	sodium phosphite Na_3PO_3
hypophosphorous acid H_3PO_2	PO_2^{-3}	hypophosphite	sodium hypophosphite Na_3PO_2

Practice Problems:

chemical name	chemical formula	chemical name	chemical formula
lithium perphosphate	Li_3PO_5	cesium hypophosphite	Cs_3PO_2
calcium phosphate	$Ca_3(PO_4)_2$	magnesium phosphate	$Mg_3(PO_4)_2$
aluminum phosphite	$AlPO_3$	gallium perphosphate	$GaPO_5$
lead(II) hypophosphite	$Pb_3(PO_2)_2$	gold(I) hypophosphite	Au_3PO_2
mercurous phosphite	Hg_3PO_3	manganese(IV) phosphite	$Mn_3(PO_3)_4$

L3. POLYATOMIC ANIONS from OXY ACID DERIVATIVES

The following chart shows how you would name the polyatomic anions from carbonic acid and its oxy acid derivatives.

oxy acid	polyatomic anion formula	polyatomic anion name	example of sodium salt
percarbonic acid H_2CO_4	CO_4^{-2}	percarbonate	sodium percarbonate Na_2CO_4
carbonic acid H_2CO_3	**CO_3^{-2}**	**carbonate**	**sodium carbonate Na_2CO_3**
carbonous acid H_2CO_2	CO_2^{-2}	carbonite	sodium carbonite Na_2CO_2
hypocarbonous acid H_2CO	CO^{-2}	hypocarbonite	sodium hypocarbonite Na_2CO

Practice Problems:

chemical name	chemical formula	chemical name	chemical formula
rubidium percarbonate	Rb_2CO_4	potassium carbonite	K_2CO_2
beryllium carbonate	$BeCO_3$	aluminum percarbonate	$Al_2(CO_4)_3$
boron carbonite	$B_2(CO_2)_3$	silver hypocarbonite	Ag_2CO
cobalt(II) hypocarbonite	$CoCO$	nickel(II) carbonate	$NiCO_3$
cuprous percarbonate	Cu_2CO_4	tin(IV) carbonite	$Sn(CO_2)_2$

L4. POLYATOMIC ANIONS from OXY ACID DERIVATIVES

The following chart shows how you would name the polyatomic anions from nitric acid and its oxy acid derivatives.

oxy acid	polyatomic anion formula	polyatomic anion name	example of sodium salt
pernitric acid HNO_4	NO_4^{-1}	pernitrate	sodium pernitrate $NaNO_4$
nitric acid HNO_3	**NO_3^{-1}**	**nitrate**	**sodium nitrate $NaNO_3$**
nitrous acid HNO_2	NO_2^{-1}	nitrite	sodium nitrite $NaNO_2$
hyponitrous acid HNO	NO^{-1}	hyponitrite	sodium hyponitrite NaNO

Practice Problems:

chemical name	chemical formula	chemical name	chemical formula
zinc pernitrate	$Zn(NO_4)_2$	antimony(V) nitrate	$Sb(NO_3)_5$
barium nitrate	$Ba(NO_3)_2$	mercury(I) nitrite	$HgNO_2$
boron nitrite	$B(NO_2)_3$	iron(II) hyponitrite	$Fe(NO)_2$
arsenic(V) hyponitrite	$As(NO)_5$	gold(III) nitrite	$Au(NO_2)_3$
plumbous nitrate	$Pb(NO_3)_2$	calcium pernitrate	$Ca(NO_4)_2$

L5. POLYATOMIC ANIONS from OXY ACID DERIVATIVES

The following chart shows how you would name the polyatomic anions from chloric acid and its oxy acid derivatives.

oxy acid	polyatomic anion formula	polyatomic anion name	example of sodium salt
perchloric acid $HClO_4$	ClO_4^{-1}	perchlorate	sodium perchlorate $NaClO_4$
chloric acid $HClO_3$	**ClO_3^{-1}**	**chlorate**	**sodium chlorate $NaClO_3$**
chlorous acid $HClO_2$	ClO_2^{-1}	chlorite	sodium chlorite $NaClO_2$
hypochlorous acid HClO	ClO^{-1}	hypochlorite	sodium hypochlorite NaClO

Practice Problems:

chemical name	chemical formula	chemical name	chemical formula
lithium perchlorate	$LiClO_4$	magnesium chlorate	$Mg(ClO_3)_2$
aluminum chlorate	$Al(ClO_3)_3$	boron chlorite	$B(ClO_2)_3$
zinc chlorite	$Zn(ClO_2)_2$	copper(II) hypochlorite	$Cu(ClO)_2$
tin(II) hypochlorite	$Sn(ClO)_2$	cobalt(II) perchlorate	$Co(ClO_4)_2$
nickelous hypochlorite	$Ni(ClO)_2$	antimony(V) chlorate	$Sb(ClO_3)_5$

M. ACID POLYATOMIC ANIONS from OXY ACIDS

Oxy acids and their derivatives with two or more hydrogen ions in their chemical formulas may form **acid polyatomic anions**. The 3 oxy acids that may form acid polyatomic anions are: H_2SO_4, H_2CO_3 and H_3PO_4. Acid polyatomic anions are formed when only one hydrogen ion Adissociates@ (separates) from the oxy acid. This leaves a negative polyatomic anion with a hydrogen ion still attached to it. Phosphoric acid (H_3PO_4) has the ability to lose **one or two** hydrogen ions and still remain an acid polyatomic anion. These acid polyatomic anions can form **acid salts** when they combine with **positive metal ions**.

oxy acid formula	**acid polyatomic anion (remove 1 or 2 H^{+1} ions)**	**acid anion name**	**examples (formula and name)**
H_2SO_4	HSO_4^{-1}	hydrogen sulfate (preferred name) or bisulfate (common name)	$NaHSO_4$ sodium hydrogen sulfate or sodium bisulfate
H_2CO_3	HCO_3^{-1}	hydrogen carbonate (preferred) or bicarbonate (common)	$NaHCO_3$ sodium hydrogen carbonate or sodium bicarbonate
H_3PO_4	$H_2PO_4^{-1}$	dihydrogen phosphate (preferred) or (no common name)	NaH_2PO_4 sodium dihydrogen phosphate
H_3PO_4	HPO_4^{-2}	monohydrogen phosphate (preferred) or biphosphate (common)	Na_2HPO_4 sodium monohydrogen phosphate or sodium biphosphate

N1. ACID ANIONS from H_2SO_4 and its DERIVATIVES

The following chart outlines the formulas and names of acid polyatomic anions derived from sulfuric acid and its derivatives. Study the chart below and identify the system used to write formulas and names for these **acid anions**.

oxy acid formula	**acid anion formula** **(remove 1 H^{+1})**	**acid anion chemical name**	**examples**
H_2SO_5	HSO_5^{-1}	hydrogen persulfate or (no common name)	$NaHSO_5$ sodium hydrogen persulfate
H_2SO_4	**HSO_4^{-1}**	**hydrogen sulfate or bisulfate**	**$NaHSO_4$ sodium hydrogen sulfate or sodium bisulfate**
H_2SO_3	HSO_3^{-1}	hydrogen sulfite or bisulfite	$NaHSO_3$ sodium hydrogen sulfite or sodium bisulfite
H_2SO_2	HSO_2^{-1}	hydrogen hyposulfite or (no common name)	$NaHSO_2$ sodium hydrogen hyposulfite

N2. ACID ANIONS from H_2CO_3 and its DERIVATIVES

Complete the chart below using the formula writing and naming system demonstrated in N1.

oxy acid formula	**acid anion formula (remove 1 H^{+1})**	**acid anion chemical name**	**examples**
H_2CO_4	HCO_4^{-1}	hydrogen percarbonate (no common name)	$NaHCO_4$ sodium hydrogen percarbonate
H_2CO_3	**HCO_3^{-1}**	**hydrogen carbonate or bicarbonate**	**$NaHCO_3$ sodium hydrogen carbonate or sodium bicarbonate**
H_2CO_2	HCO_2^{-1}	hydrogen carbonite or bicarbonite	$NaHCO_2$ sodium hydrogen carbonite or sodium bicarbonite
H_2CO	HCO^{-1}	hydrogen hypocarbonite (no common name)	NaHCO sodium hydrogen hypocarbonite

N3. ACID ANIONS from H_3PO_4 and its DERIVATIVES

Complete the table below using the formula writing and naming system demonstrated in N1. Since one or two hydrogens can dissociate (separate) from these acids without losing all the hydrogens, a prefix must be used to indicate how many hydrogen ions remain bonded to the acid anion.

oxy acid formula	**acid anion formula** **(remove 1 H^{+1})**	**acid anion chemical name**	**examples**
H_3PO_5	$H_2PO_5^{-1}$	dihydrogen perphosphate (no common name)	NaH_2PO_5 sodium dihydrogen perphosphate
H_3PO_4	**$H_2PO_4^{-1}$**	**dihydrogen phosphate** **(no common name)**	**NaH_2PO_4** **sodium dihydrogen phosphate**
H_3PO_3	$H_2PO_3^{-1}$	dihydrogen phosphite (no common name)	NaH_2PO_3 sodium dihydrogen phosphate
H_3PO_2	$H_2PO_2^{-1}$	dihydrogen hypophosphite (no common name)	NaH_2PO_2 sodium dihydrogen hypophosphite

N4. ACID ANIONS from H_3PO_4 and DERIVATIVES

Complete the following table using the formula writing and naming system demonstrated in N1, N2 and N3.

oxy acid formula	**acid anion formula** **(remove 2 H^{+1})**	**acid anion chemical name**	**examples**
H_3PO_5	HPO_5^{-2}	monohydorgen perphosphate (no common name)	Na_2HPO_5 sodium monohydrogen perphosphate
H_3PO_4	**HPO_4^{-2}**	**monohydrogen phosphate or biphosphate**	**Na_2HPO_4 sodium monohydrogen phosphate or sodium biphosphate**
H_3PO_3	HPO_3^{-2}	monohydrogen phosphite or biphosphite	Na_2HPO_3 sodium monohydrogen phosphite or sodium biphosphite
H_3PO_2	HPO_2^{-2}	monohydrogen hypophosphite (no common name)	Na_2HPO_2 sodium monohydrogen hypophosphite

Worksheet MN

chemical name	chemical formula	chemical name	chemical formula
sodium hydrogen sulfate	$NaHSO_4$	lithium hydrogen persulfate	$LiHSO_5$
potassium bicarbonate	$KHCO_3$	rubidium hydrogen hypophosphite	RbHCO
magnesium dihydrogen phosphite	$Mg(H_2PO_3)_2$	calcium dihydrogen hypophosphite	$Ca(H_2PO_2)_2$
aluminum monohydrogen hypophosphite	$Al_2(HPO_2)_3$	boron monohydrogen phosphite	$B_2(HPO_3)_3$
zinc bisulfite	$Zn(HSO_3)_2$	silver hydrogen sulfate	$AgHSO_4$
barium hydrogen carbonite	$Ba(HCO_2)_2$	strontium monohydrogen hypophosphite	$SrHPO_2$
nickel(II) dihydrogen perphosphate	$Ni(H_2PO_5)_2$	copper(I) hydrogen percarbonate	$CuHCO_4$
cupric hydrogen hypocarbonite	$Cu(HCO)_2$	iron(II) dihydrogen phosphite	$Fe(H_2PO_3)_2$
iron(III) biphosphite	$Fe_2(HPO_3)_3$	cobalt(III) hydrogen hyposulfite	$Co(HSO_2)_3$
mercurous hydrogen persulfate	$HgHSO_5$	mercury(I) hydrogen sulfite	$HgHSO_3$
tin(IV) biphosphate	$Sn(HPO_4)_2$	calcium hydrogen carbonite	$Ca(HCO_2)_2$
sodium hydrogen carbonate	$NaHCO_3$	manganese(IV) hydrogen carbonate	$Mn(HCO_3)_4$
plumbic dihydrogen hypophosphite	$Pb(H_2PO_2)_4$	lead(IV) dihydrogen phosphate	$Pb(H_2PO_4)_4$
arsenic(V) monohydrogen perphosphate	$As_2(HPO_5)_5$	antimony(V) monohydrogen perphosphate	$Sb_2(HPO_5)_5$
aurous hydrogen carbonite	$AuHCO_2$	arsenic(III) dihydrogen perphosphate	$As(H_2PO_5)_3$

O. MISCELLANEOUS POLYATOMIC IONS

Other polyatomic anions and cations are commonly found in chemical compounds. The following are just two examples of other polyatomic ions. Complete the table using rules you have learned in Part 2 of this independent study.

polyatomic ion name	**ammonium**	**hydroxide**
polyatomic ion symbol	**NH_4^{+1}**	**OH^{-1}**
example of chemical formula with this ion	NH_4Cl	NaOH
chemical name of example above	ammonium chloride	sodium hydroxide

MISCELLANEOUS POLYATOMIC IONS - more examples

The following chemical formulas and chemical names contain other common polyatomic ions. Use the "**Oxidation States**" sheet to determine the formula of the ion being used and its charge and complete this table.

chemical name	**chemical formula**	**chemical name**	**chemical formula**
sodium thiocyanate	NaSCN	magnesium dichromate	$MgCr_2O_7$
calcium permanganate	$Ca(MnO_4)_2$	lead(II) or plumbous cyanide	$Pb(CN)_2$
ferrous acetate	$Fe(CH_3CO_2)_2$	aluminum cyanate	$Al(OCN)_3$
copper(II) chromate	$CuCrO_4$	ammonium thiocyanate	NH_4SCN
gold(III) dichromate	$Au_2(Cr_2O_7)_3$	lithium acetate	$LiCH_3CO_2$
arsenic cyanate	$As(OCN)_5$	potassium permanganate	$KMnO_4$
potassium cyanide	KCN	lead(IV) or plumbic chromate	$Pb(CrO_4)_2$
boron hydroxide	$B(OH)_3$	ammonium hypocarbonite	$(NH_4)_2CO$