

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 sulfate (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
	H_2SO_4
carbonic acid	H_2CO_3
	HNO_3
chloric acid	HClO_3
	HFO_3
	HBrO_3
	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 _____ acid (called "per-ic" acid)
- + **OXY ACID** = sulfuric acid (called "ic" acid, AKA ~~another acid~~)
- + if **ONE OXYGEN ATOM IS REMOVED**, remove "ic" and add "ous" to acid name
= _____ ous acid (called "ous" acid)
- + if **TWO OXYGEN ATOMS ARE REMOVED**, add prefix "hypo" to "ous" acid name =
hypo _____ ous 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)		
no change ("ic" acid)	sulfuric acid	H ₂ SO ₄
remove one oxygen atom(*) ("ous" acid)		
remove two oxygen atoms(*) ("hypo-ous" acid)		

(*) 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)		
no change ("ic" acid)	phosphoric acid	
remove one oxygen atom ("ous" acid)		
remove two oxygen atoms ("hypo-ous" acid)		

change in oxy acid formula	oxy acid name	oxy acid formula
add one oxygen atom ("per-ic" acid)		
no change ("ic" acid)	carbonic acid	
remove one oxygen atom ("ous" acid)		
remove two oxygen atoms ("hypo-ous" acid)		

change in oxy acid formula	oxy acid name	oxy acid formula
add one oxygen atom ("per-ic" acid)		
no change ("ic" acid)	nitric acid	
remove one oxygen atom ("ous" acid)		
remove two oxygen atoms ("hypo-ous" acid)		

change in oxy acid formula	oxy acid name	oxy acid formula
add one oxygen atom ("per-ic" acid)		
no change ("ic" acid)	chloric acid	
remove one oxygen atom ("ous" acid)		
remove two oxygen atoms ("hypo-ous" acid)		

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_5
fluoric acid			HFO_2
hypophosphorous acid			H_3PO_5
percarbonic acid			H_2CO_3
pernitric acid			HNO
bromous acid			HBrO_4
hypoiodous acid			HIO_3
perfluoric acid			H_2SO_2
phosphoric acid			HClO
carbonic acid			HNO_2
nitrous acid			H_2CO_4
hypochlorous acid			H_3PO_4

Oxy acids and their derivatives dissociate (separate from) their positive hydrogen ions (H^{+1}), 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 "ic" acid always results in the "ate" 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
	SO_4^{-2}	sulfate	sodium sulfate Na_2SO_4
	CO_3^{-2}	carbonate	sodium carbonate Na_2CO_3
	NO_3^{-1}	nitrate	
	ClO_3^{-1}	chlorate	
fluoric acid			
bromic acid			
iodic acid			

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 ("ic" acids always result in "ate" ions)	sodium persulfate Na_2SO_5
sulfuric acid H_2SO_4	SO_4^{-2}	sulfate ("ic" acids always result in "ate" ions)	sodium sulfate Na_2SO_4
sulfurous acid H_2SO_3	SO_3^{-2}	sulfite ("ous" acids always result in "ite" ions)	sodium sulfite Na_2SO_3
hyposulfurous acid H_2SO_2	SO_2^{-2}	hyposulfite ("ous" acids always result in "ite" 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			$\text{K}_2\text{S}_2\text{O}_8$
aluminum sulfate			$\text{Al}_2(\text{SO}_4)_3$
copper(I) sulfite			Cu_2SO_3
ferrous hyposulfite $\text{Fe}^{+2} \text{SO}_2^{-2}$	FeSO_2		$\text{Fe}_2(\text{SO}_3)_3$
nickel(III) persulfate $\text{Ni}^{+3} \text{SO}_5^{-2}$	$\text{Ni}_2(\text{SO}_5)_3$		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
phosphoric acid H_3PO_4	PO_4^{-3}	phosphate	

Practice Problems:

chemical name	chemical formula	chemical name	chemical formula
lithium perphosphate			Cs_3PO_2
calcium phosphate			$\text{Mg}_3(\text{PO}_4)_2$
aluminum phosphite			GaPO_5
lead(II) hypophosphite			Au_3PO_2
mercurous phosphite			$\text{Mn}_3(\text{PO}_3)_4$

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
carbonic acid H_2CO_3	CO_3^{-2}	carbonate	

Practice Problems:

chemical name	chemical formula	chemical name	chemical formula
rubidium percarbonate			K_2CO_2
beryllium carbonate			$\text{Al}_2(\text{CO}_4)_3$
boron carbonite			Ag_2CO
cobalt(II) hypocarbonite			NiCO_3
cuprous percarbonate			$\text{Sn}(\text{CO}_2)_2$

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
nitric acid HNO_3	NO_3^{-1}	nitrate	

Practice Problems:

chemical name	chemical formula	chemical name	chemical formula
zinc pernitrate			$\text{Sb}(\text{NO}_3)_5$
barium nitrate			HgNO_2
boron nitrite			$\text{Fe}(\text{NO})_2$
arsenic(V) hyponitrite			$\text{Au}(\text{NO}_2)_3$
plumbous nitrate			$\text{Ca}(\text{NO}_4)_2$

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
chloric acid HClO_3	ClO_3^{-1}	chlorate	

Practice Problems:

chemical name	chemical formula	chemical name	chemical formula
lithium perchlorate			$\text{Mg}(\text{ClO}_3)_2$
aluminum chlorate			$\text{B}(\text{ClO}_2)_3$
zinc chlorite			$\text{Cu}(\text{ClO})_2$
tin(II) hypochlorite			$\text{Co}(\text{ClO}_4)_2$
nickelous hypochlorite			$\text{Sb}(\text{ClO}_3)_5$

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 dissociates (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	$\text{H}_2\text{PO}_4^{-1}$	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
		(no common name)	
H_2CO_3	HCO_3^{-1}	hydrogen carbonate or bicarbonate	NaHCO_3 sodium hydrogen carbonate or sodium bicarbonate
		(no common name)	

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
		(no common name)	
H_3PO_4	$\text{H}_2\text{PO}_4^{-1}$	dihydrogen phosphate (no common name)	NaH_2PO_4 sodium dihydrogen phosphate
		(no common name)	
		(no common name)	

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
		(no common name)	
H_3PO_4	HPO_4^{-2}	monohydrogen phosphate or biphosphate	Na_2HPO_4 sodium monohydrogen phosphate or sodium biphosphate
		(no common name)	

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chemical name	chemical formula	chemical name	chemical formula
sodium hydrogen sulfate			LiHSO_5
potassium bicarbonate			RbHCO
magnesium dihydrogen phosphite			$\text{Ca}(\text{H}_2\text{PO}_2)_2$
aluminum monohydrogen hypophosphite			$\text{B}_2(\text{HPO}_3)_3$
zinc bisulfite			AgHSO_4
barium hydrogen carbonite			SrHPO_2
nickel(II) dihydrogen perphosphate			CuHCO_4
cupric hydrogen hypocarbonite			$\text{Fe}(\text{H}_2\text{PO}_3)_2$
iron(III) biphosphite			$\text{Co}(\text{HSO}_2)_3$
mercurous hydrogen persulfate			HgHSO_3
tin(IV) biphosphate			$\text{Ca}(\text{HCO}_2)_2$
sodium hydrogen carbonate			$\text{Mn}(\text{HCO}_3)_4$
plumbic dihydrogen hypophosphite			$\text{Pb}(\text{H}_2\text{PO}_4)_4$
arsenic(V) monohydrogen perphosphate			$\text{Sb}_2(\text{HPO}_5)_5$
aurous hydrogen carbonite			$\text{As}(\text{H}_2\text{PO}_5)_3$

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	$(\text{NH}_4)_2\text{SO}_3$	$\text{Fe}(\text{OH})_2$
chemical name of example above		

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 or oxidation state of the ion being used.

chemical name	chemical formula	chemical name	chemical formula
sodium thiocyanate			MgCr_2O_7
calcium permanganate			$\text{Pb}(\text{CN})_2$
ferrous acetate			$\text{Al}(\text{OCN})_3$
copper(II) chromate			NH_4SCN
gold(III) dichromate			LiCH_3CO_2
arsenic cyanate			KMnO_4
potassium cyanide			$\text{Pb}(\text{CrO}_4)_2$
boron hydroxide			$(\text{NH}_4)_2\text{CO}$