

Writing and Naming Inorganic Compounds

Naming

IUPAC is an agency that makes rules for naming chemicals
Many compounds also have common names

Inorganic compounds

Compounds that do not contain carbon, EXCEPT
 CO_2 and CO_3^{2-} are considered inorganic
 CO_2 is carbon dioxide
 CO_3^{2-} is carbonate ion

Ionic Compounds – Definitions and examples

Contain at least one metal and at least one nonmetal
Form salts consisting of formula units

Binary Ionic compounds – contain two different atoms

KCl is potassium chloride – contains two different atoms, K, Cl
The cation is potassium ion, K^+
The anion is chloride, Cl^-
 CaCl_2 is calcium chloride – contains two different atoms Ca, Cl
The cation is calcium ion, Ca^{2+}
The anion is chloride, Cl^-

Ternary Ionic compounds – contain three different atoms

Na_2SO_4 is sodium sulfate – contains three different atoms, Na, S and O
The cation is sodium ion, Na^+
The anion is sulfate, SO_4^{2-}
 K_3PO_4 is potassium phosphate. It contains three different atoms, K, P, O
The cation is potassium ion, K^+
The anion is phosphate PO_4^{3-}

Covalent Compounds – Definitions and examples

Contain two or more nonmetals
Form molecules held together by covalent bonds

Binary Molecular compounds – two different nonmetal atoms

Examples with common names
 NH_3 – ammonia

H₂O – water

N₂H₄ - hydrazine

Examples with systematic names

CO₂ – carbon dioxide

CO – carbon monoxide

N₂O – dinitrogen monoxide

Aqueous Acids

Note that acids often start with an H, but not all compounds that start with H are acids.

Acids form an aqueous solution when dissolved in water.

Indicate aqueous acids by placing an (aq) after the formula.

The two acid categories below are for writing and naming aqueous acids.

Binary aqueous acids

Consist of two different atoms, where the first atom is H.

HF(aq) – hydrofluoric acid

HCl(aq) – hydrochloric acid

HBr(aq) – hydrobromic acid

HI(aq) – hydroiodic acid

Ternary aqueous acids

Made up of three different atoms, one is hydrogen, one is oxygen

H₂SO₄(aq) – sulfuric acid

HNO₃(aq) – nitric acid

H₃PO₄(aq) – phosphoric acid

H₂CO₃(aq) – carbonic acid

Ionic compounds – Writing and Naming

Ions

An ion is an atom or group of atoms with a charge

A polyatomic ion is a group of atoms with a charge

Cation – ion with a positive charge.

Examples: K⁺ (potassium ion), NH₄⁺ (ammonium ion)

Anion – ion with a negative charge.

Examples: F⁻ (fluoride ion), SO₄²⁻ (sulfate ion)

Naming Cations

For monatomic (one atom) cations that form ions with only one charge, use the name of the metal followed by the word 'ion.'

Cations named using this system include the main group metals (except cations of Sn and Pb) as well as the transition metal ions Ag⁺, Zn²⁺, and Cd²⁺.

All the metals named with this system are highlighted **yellow** in the periodic table below.

Examples:

K^+ is potassium ion

Ca^{2+} is calcium ion

Al^{3+} is aluminum ion

Ag^+ is silver ion

Zn^{2+} is zinc ion

Cd^{2+} is cadmium ion

As discussed previously, \

Group IA metals form +1 ions

Group IIA metals form +2 ions

Group IIIA metals form +3 ions

For monatomic (one atom) cations that form ions with more than one charge, use the Stock system of naming a Roman numeral gives the charge.

Use the name of the metal, a Roman numeral in parentheses, and the word 'ion'

Cations named using this system include the transition metal ions (except Ag^+ , Zn^{2+} , and Cd^{2+}), as well as the main group metal ions of Sn and Pb.

All the metals named with the Stock system are highlighted **blue** in the periodic table below.

Transition metals form multiple ions, except for Ag, Zn, and Cd

Fe^{2+} is called the iron(II) ion

Fe^{3+} is called the iron(III) ion

Ti^{4+} is called the titanium(IV) ion

Cr^{6+} is called the chromium(VI) ion

Mn^{7+} is called the manganese(VII) ion

(Note: a few other metals form multiple ions, but not for this course)

Most transition metals form a +2 ion as well as others

The 2s valence electrons are lost when forming a +2 ion

Periodic Table of the Elements

Atomic number (Z) — Predicted electron configuration. Dashed lines indicate exceptions.
 Symbol — Normal font=solid, outline=liquid, italic=gas at room temperature
 name
 atomic mass

IA +1	IIA +2	IIIB	IVB	VB	VIB	VIIA	VIIIA	IB	IIB	IIIA +3	IVA +4/-4	VA -3	VIA -2	VIIA -1	VIIIA 0 Chn		
1 1s ¹ H Hydrogen 1.008	s block														2 1s ² He Helium 4.003		
3 2s ¹ Li Lithium 6.941	4 2s ² Be Beryllium 9.012	p block															
11 3s ¹ Na Sodium 22.990	12 3s ² Mg Magnesium 24.305	Transition Metals d block															
19 4s ¹ K Potassium 39.098	20 4s ² Ca Calcium 40.078	21 3d ¹ Sc Scandium 44.956	22 3d ² Ti Titanium 47.867	23 3d ³ V Vanadium 50.942	24 3d ⁴ Cr Chromium 51.996	25 3d ⁵ Mn Manganese 54.938	26 3d ⁶ Fe Iron 55.845	27 3d ⁷ Co Cobalt 58.933	28 3d ⁸ Ni Nickel 58.693	29 3d ⁹ Cu Copper 63.546	30 3d ¹⁰ Zn Zinc 65.39	31 4s ¹ Ga Gallium 69.723	32 4s ² Ge Germanium 72.61	33 4p ¹ As Arsenic 74.922	34 4p ² Se Selenium 78.96	35 4p ³ Br Bromine 79.904	36 4p ⁴ Kr Krypton 83.80
37 5s ¹ Rb Rubidium 85.468	38 5s ² Sr Strontium 87.62	39 4d ¹ Y Yttrium 88.906	40 4d ² Zr Zirconium 91.224	41 4d ³ Nb Niobium 92.906	42 4d ⁴ Mo Molybdenum 95.94	43 4d ⁵ Tc Technetium (98)	44 4d ⁶ Ru Ruthenium 101.07	45 4d ⁷ Rh Rhodium 102.906	46 4d ⁸ Pd Palladium 106.42	47 4d ⁹ Ag Silver 107.868	48 4d ¹⁰ Cd Cadmium 112.411	49 5s ¹ In Indium 114.818	50 5s ² Sn Tin 118.710	51 5p ¹ Sb Antimony 121.760	52 5p ² Te Tellurium 127.60	53 5p ³ I Iodine 126.904	54 5p ⁴ Xe Xenon 131.29
55 6s ¹ Cs Cesium 132.905	56 6s ² Ba Barium 137.327	57 5d ¹ La Lanthanum 138.906	72 5d ² Hf Hafnium 178.49	73 5d ³ Ta Tantalum 180.948	74 5d ⁴ W Tungsten 183.84	75 5d ⁵ Re Rhenium 186.207	76 5d ⁶ Os Osmium 190.23	77 5d ⁷ Ir Iridium 192.217	78 5d ⁸ Pt Platinum 195.078	79 5d ⁹ Au Gold 196.967	80 5d ¹⁰ Hg Mercury 200.59	81 6s ¹ Tl Thallium 204.383	82 6s ² Pb Lead 207.2	83 6p ¹ Bi Bismuth 208.980	84 6p ² Po Polonium (209)	85 6p ³ At Astatine (210)	86 6p ⁴ Rn Radon (222)
87 7s ¹ Fr Francium (223)	88 7s ² Ra Radium (226)	89 5d ¹ Ac Actinium (227)	104 6d ² Rf Rutherfordium (261)	105 6d ³ Db Dubnium (262)	106 6d ⁴ Sg Seaborgium (266)	107 6d ⁵ Bh Bohrium (264)	108 6d ⁶ Hs Hassium (277)	109 6d ⁷ Mt Meitnerium (268)	110 6d ⁸ Ds Darmstadtium (271)	111 6d ⁹ Rg Roentgenium (272)	112 6d ¹⁰ Cn Copernicium (278)	113 7s ¹ Uut Ununtrium (284)	114 7s ² Uuq Ununquadium (289)	115 7p ¹ Uup Ununpentium (288)	116 7p ² Uuh Ununhexium (292)	117 7p ³ Uuq Ununseptium (294)	118 7p ⁴ Uuo Ununoctium (294)

Polyatomic (more than one atom) cations

There is only one polyatomic cation used in this course, NH_4^+ (ammonium ion). The ammonium ion forms compounds that are ionic in behavior (and naming).

Naming Anions

Monatomic (one atom) anions (nonmetals usually form anions)

Drop the ending of the name of the element and add the suffix '-ide'

The red indicates the portion that is dropped

Cl^- is called chloride (chlorine)

O^{2-} is called oxide (oxygen)

N^{3-} is called nitride (nitrogen)

Se^{2-} is called selenide (selenium)

Group VIIA nonmetals form -1 ions

Group VIA nonmetals form -2 ions

Group VA nonmetals form -3 ions

Polyatomic (more than one atoms) anions

Many polyatomic anions contain oxygen – called oxyanions

Oxyanions have names that end in '-ate' or '-ite'

Examples of '-ate' oxyanions

The oxyanion NO_3^- is nitrate

The oxyanion SO_4^{2-} is sulfate

The oxyanion PO_4^{3-} is phosphate

The oxyanion ClO_3^- is chlorate

Examples of '-ite' oxyanions

Take away 1 oxygen and keep the same charge

The oxyanion NO_2^- is nitrite

The oxyanion SO_3^{2-} is sulfite

The oxyanion PO_3^{3-} is phosphite

The oxyanion ClO_2^- is chlorite

Two polyatomic anions sound like elements

These have an '-ide' ending but they are not elements

The polyatomic anion CN^- is cyanide

The polyatomic anion OH^- is hydroxide

Examples of Writing and Naming Ionic Compounds

A *formula unit* is the simplest representation of an ionic compound

Total charge on the compound must be zero = cations + anions

Name the cation (usually metal or ammonium ion) first and then the anion

Charges must be balanced

$\text{Na}^+ + \text{Cl}^-$ forms NaCl – sodium chloride, where $+1 + -1 = 0$

$\text{Ca}^{2+} + \text{Cl}^-$ forms CaCl_2 – calcium chloride, where $+2 + 2(-1) = 0$

$\text{Ca}^{2+} + \text{S}^{2-}$ forms CaS – calcium sulfide, where $+2 + -2 = 0$

$\text{Li}^+ + \text{S}^{2-}$ forms Li_2S – lithium sulfide, where $2(+1) + -2 = 0$

Notice the crossover rule:

Charge on the metal becomes the subscript on the nonmetal

Charge on the nonmetal becomes the subscript on the metal

Remember to reduce the result

Use parenthesis to indicate more than one polyatomic ion

$\text{Al}^{3+} + \text{SO}_4^{2-}$ forms $\text{Al}_2(\text{SO}_4)_3$ – aluminum sulfate

$\text{NH}_4^+ + \text{PO}_4^{3-}$ forms $(\text{NH}_4)_3\text{PO}_4$ – ammonium phosphate

$\text{Ca}^{2+} + \text{O}^{2-}$ forms CaO – calcium oxide (remember to reduce)

$\text{Ti}^{4+} + \text{O}^{2-}$ forms TiO_2 – titanium(IV) oxide (remember to reduce!)

Calculating charges for metals that form more than one ions

The total charge of the ions in an ionic compound must sum to zero

Calculate the charge on iron in Fe_2S_3

S is -2 because it is a nonmetal in Group VIA

The total charge on 3 S atoms is $3(-2) = -6$

The total positive charge must be +6

The +6 charge goes to 2 iron atoms

Charge on each iron atom must be $+6 / 2$ or +3

Charge on each iron atom is +3

The stock name is iron(III) sulfide

Use the (III) because iron is a transition metal other than Ag, Cd, or Zn

What is the Stock name of Hg_2O ?

O is -2 because it is a nonmetal in Group VIA

The total positive charge must be +2 because the overall charge must be 0

Charge on each Hg must be $+2 / 2 = +1$

The Stock name is mercury(I) oxide

What is the formula for Manganese(IV) oxide?

Oxide is -2

Manganese is +4

The correct formula is MnO_2 (remember to reduce!)

What is the formula for chromium(III) sulfate?

Sulfate, SO_4^{2-} , is -2

Chromium is +3

The correct compound is $\text{Cr}_2(\text{SO}_4)_3$

Name Na_2CO_3 – sodium carbonate

Name $\text{Cr}(\text{SO}_4)_2$ – chromium(IV) sulfate (transition metal)

Covalent Compounds – Writing and Naming

A molecule is the simplest representation of a molecular compound

Binary Molecular Compounds

Use prefixes to indicate the number of atoms in a molecular compound

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

Name the first atom, using a prefix if needed

Note that the last 'a' or 'o' in the prefixes is dropped if the element name starts with a vowel

If there is only one of the *first* atom, skip the prefix 'mono'

Name the second atom, using a prefix if needed, and adding the suffix '-ide'

CO_2 is called carbon dioxide (skip prefix mono for first atom)

CO is called carbon monoxide (skip prefix 'mono-' for first atom, dropped 'o' before oxide)

SF_6 is called sulfur hexafluoride (skip prefix 'mono-' for first atom)

P_4O_6 is called tetraphosphorous hexoxide (note: 'a' is dropped from hexa)

P_4S_6 is called tetraphosphorous hexasulfide

PO_5 is called phosphorous pentoxide (note: 'a' is dropped from penta)

PS_5 is called phosphorous pentasulfide

Binary Aqueous Acids

Aqueous acids are dissolved in water

$HF(aq)$ – hydrofluoric acid

$HCl(aq)$ – hydrochloric acid

$HBr(aq)$ - hydrobromic acid

$HI(aq)$ – hydroiodic acid

Ternary Aqueous Acids

Aqueous acids are dissolved in water

$HNO_3(aq)$ is nitric acid

$HNO_2(aq)$ is nitrous acid

$H_2SO_4(aq)$ is sulfuric acid

$H_2SO_3(aq)$ is sulfurous acid

$H_3PO_4(aq)$ is phosphoric acid

$H_3PO_3(aq)$ is phosphorous acid