Nomenclature for ionic compounds

Nomenclature is a system of naming. This worksheet presents a widely used system of nomenclature for ionic compounds.

There are two types of metal cations with different naming conventions discussed separately.

- fixed charge (single charge) cations (Never use a Roman numeral)
- variable charge (multiple charge) cations (Always use a Roman numeral)

Cations with a single, fixed charge

Cations have a positive charge. They are formed from metals, which lie on the left side of the periodic table. The main group (Groups 1-8) metals form cations with a single, fixed charge. The charge is the same as the Group (column) number on the periodic table. The cation name is formed by adding the word "ion" after the element name. For example, the element sodium (Na) is found in Group 1. It ionizes to form the "sodium ion" represented as Na^+. The charge is +1 because it is in Group 1.

Anions have a negative charge. They are formed from nonmetals, which lie on the right side of the periodic table. The negative charge is found using the **Octet Rule** as eight (8) minus the Group number. Anions always have a single, fixed charge. The anion name is formed by changing the element name suffix to "-ide" and adding the word "ion" after the element name. For example, the element chlorine (Cl) is found in Group 7. It ionizes to form the "chloride ion" represented as Cl^-. The charge is -1 because it is in Group 7, and 8 - 7 = 1.

Ionic compounds are formed by cation-anion pairs in electrically neutral ratios. They are named using the cation name first, followed by the anion name, excluding the word "ion." For example, sodium ion (Na^+) and chloride ion (Cl^-) form the compound sodium chloride. Its formula is NaCl, which is electrically neutral because sodium ion is +1 and chloride ion is -1. As a second example, magnesium chloride has the formula $MgCl_2$. The subscripts indicate 2 chloride ions (Cl^-) per 1 magnesium ion (Mg^{2+}). The subscript "1" is always implied and never written.

Note: There is <u>never</u> any charge indicated in the name of a compound having a cation with a single, fixed charge. The single, fixed charge is obvious to a chemist.

 Name: _____

Exercise 1. Provide the name or formula for each ion:

Cl^-	chloride ion	Li^+	lithium ion
Br^-	bromide ion	Na^+	sodium ion
F^-	fluoride ion	K^+	potassium ion
S^{2-}	sulfide ion	Mg^{2+}	magnesium ion
O^{2-}	oxide ion	Ca^{2+}	calcium ion
N^{3-}	nitride ion	Al^{3+}	aluminum ion
P^{3-}	phosphide ion	Ba^{2+}	barium ion
C^{4-}	carbide ion	B^{3+}	boron ion

Exercise 2. Complete the table of neutral ionic compounds with the formulas and names for each cation-anion pair.

	Cl^-	I^-	S^{2-}	O^{2-}	Br^-	N^{3-}
Na^+	$NaCl$ sodium chloride	NaI sodium iodide	Na_2S sodium sulfide	Na_2O sodium oxide	$NaBr$ sodium bromide	Na_3N sodium nitride
K^+	KCl potassium chloride	KI potassium iodide	K_2S potassium sulfide	K_2O potassium oxide	KBr potassium bromide	K_3N potassium nitride
Mg^{2+}	$MgCl_2$ magnesium chloride	MgI_2 magnesium iodide	MgS magnesium sulfide	MgO magnesium oxide	$MgBr_2$ magnesium bromide	Mg_3N_2 magnesium nitride
Al^{3+}	$AlCl_3$ aluminum chloride	AlI_3 aluminum iodide	Al_2S_3 aluminum sulfide	Al_2O_3 aluminum oxide	$AlBr_3$ aluminum bromide	AlN aluminum nitride

Cations with a variable/multiple charges

Some transition metals have multiple possible cation charges. A roman numeral (I, II, III, IV, V, …) must be used in the cation and ionic compound naming system to distinguish between the charges. For example, iron (Fe) can form the iron (II) ion and also the iron (III) ion, denoted Fe^{2+} and Fe^{3+}, respectively. Iron (II) oxide and iron (III) oxide are distinct compounds, with electrically neutral formulas FeO and Fe_2O_3, respectively.

Exercise 3. Provide the formula for each compound.

iron (II) oxide	FeO
iron (III) oxide	Fe_2O_3
lead (II) chloride	$PbCl_2$
lead (IV) iodide	PbI_4
cobalt (II) chloride	$CoCl_2$
cobalt (III) chloride	$CoCl_3$

Mixed cation types

The first step in naming an ionic compound is to determine whether or not the cation can exhibit multiple charges. This requires memorization. Learn the following procedure.

1. The main group (Groups 1-8) elements always have a single charge, determined by the column on the periodic table.
2. Silver and zinc are the only transition metals with a single charge. Memorize the ionic charges for Ag^+ and Zn^{2+}.
3. All other transition metals have multiple charges. Use a roman numeral to indicate the cation charge, which can be figured out from the given information.

Exercise 4. Provide the name for each compound.

FeO	iron (II) oxide
NaCl	sodium chloride
$CuBr_2$	copper (II) bromide
ZnO	zinc oxide
K_3P	potassium phosphide
CaS	calcium sulfide
Ag_2S	silver sulfide
CoI_3	cobalt (III) iodide
Be_3N_2	berylium nitride

Polyatomic ions

Polyatomic ions are charged groups of atoms. An example is ammonium ion, NH_4^+. It has five atoms (one nitrogen and four hydrogens) that share a charge of +1. The polyatomic ions remain intact, and parentheses may be required when using subscripts. For example, ammonium chloride is NH_4Cl and ammonium sulfide is $(NH_4)_2S$. Ammonium is the only polyatomic cation. Common anions are shown in Table 1.

Table 1. Polyatomic ions

Ion name	Ion Formula
ammonium	NH_4^+
cyanide	CN^-
hydroxide	OH^-
perchlorate	ClO_4^-
chlorate	ClO_3^-
chlorite	ClO_2^-
hypochlorite	ClO^-
bromate	BrO_3^-
iodate	IO_3^-
nitrate	NO_3^-
sulfate	SO_4^{2-}
carbonate	CO_3^{2-}
hydrogen carbonate (bicarbonate)	HCO_3^-
phosphate	PO_4^{3-}
hydrogen phosphate	HPO_4^{2-}
dihydrogen phosphate	$H_2PO_4^-$
permanganate	MnO_4^-
chromate	CrO_4^{2-}
dichromate	$Cr_2O_7^{2-}$
acetate	$C_2H_3O_2^-$ *or* $CH_3CO_2^-$

There are many polyatomic anions. Many occur in **families of names**.

Start by learning the polyatomic ions ending with "-ate" such as chlorate (ClO_3^-), nitrate (NO_3^{--}), sulfate (SO_4^{2-}), carbonate (CO_3^{2-}), and phosphate (PO_4^{3-}).

The corresponding "-ite" ion name has one less oxygen and the same charge. For example, chlorite ion is ClO_2^-. Less commonly used names are the "per__-ate" and "hypo__-ite" forms to indicate different numbers of oxygen.

Key in on the chlorate family in Table 1 to construct names for other ions. For example, sulfite (not in the table) would be SO_3^{2-}, because it has the same charge and one less oxygen than sulfate (SO_4^{2-} in the table).

Sometimes "bi-" indicates H^+ has attached. For example, bicarbonate (HCO_3^-) and carbonate (CO_3^{2-}).

Hydroxide, cyanide, permanganate, acetate, and chromate/dichromate are common polyatomics that do <u>not</u> occur in families.

Exercise 5. Complete the table of neutral ionic compounds with the formulas and names for each cation-anion pair, similar to Exercise 2.

	SO_4^{2-}	NO_3^-	PO_4^{3-}	CO_3^{2-}	ClO_3^-	OH^-
Na^+	Na_2SO_4 sodium sulfate	$NaNO_3$ sodium nitrate	Na_3PO_4 sodium phosphate	Na_2CO_3 sodium carbonate	$NaClO_3$ sodium chlorate	NaOH sodium hydroxide
Al^{3+}	$Al_2(SO_4)_3$ aluminum sulfate	$Al(NO_3)_3$ aluminum nitrate	$AlPO_4$ aluminum phosphate	$Al_2(CO_3)_3$ aluminum carbonate	$Al(ClO_3)_3$ aluminum chlorate	$Al(OH)_3$ aluminum hydroxide
Ba^{2+}	$BaSO_4$ barium sulfate	$Ba(NO_3)_2$ barium nitrate	$Ba_3(PO_4)_2$ barium phosphate	$BaCO_3$ barium carbonate	$Ba(ClO_3)_2$ barium chlorate	$Ba(OH)_2$ barium hydroxide
NH_4^+	$(NH_4)_2SO_4$ ammonium sulfate	NH_4NO_3 ammonium nitrate	$(NH_4)_3PO_4$ ammonium phosphate	$(NH_4)_2CO_3$ ammonium carbonate	NH_4ClO_3 ammonium chlorate	NH_4OH ammonium hydroxide
Cu^+	Cu_2SO_4 copper (I) sulfate	$CuNO_3$ copper (I) nitrate	Cu_3PO_4 copper (I) phosphate	Cu_2CO_3 copper (I) carbonate	$CuClO_3$ copper (I) chlorate	CuOH copper (I) hydroxide

Exercise 6. Provide the formula for each compound.

sodium sulfate ____Na_2SO_4____

sodium bisulfate ____$NaHSO_4$____

sodium sulfite ____Na_2SO_3____

sodium sulfide ____Na_2S____

copper (I) sulfate ____Cu_2SO_4____

copper (II) sulfite ____$CuSO_3$____

copper (II) sulfide ____CuS____

Exercise 7. Provide the formula for each compound.

nickel (III) carbonate	$Ni_2(CO_3)_3$
calcium nitrate	$Ca(NO_3)_2$
copper (II) acetate	$Cu(CH_3COO)_2$
potassium phosphate	K_3PO_4
silver acetate	$AgCH_3COO$
zinc chromate	$ZnCrO_4$
tin (II) nitrate	$Sn(NO_3)_2$
tin (II) nitrite	$Sn(NO_2)_2$
ammonium bicarbonate	NH_4HCO_3
copper (II) sulfite	$CuSO_3$
sodium hydroxide	NaOH
potassium cyanide	KCN
potassium phosphide	K_3P

Exercise 8. Provide the name for each compound.

CuCN	copper (I) cyanide
FeO	iron (II) oxide
ZnO	zinc oxide
Al_2O_3	aluminum oxide
AgCl	silver chloride
NH_4NO_3	ammonium nitrate
$NaNO_3$	sodium nitrate
$NaNO_2$	sodium nitrite
$Ca(NO_2)_2$	calcium nitrite
$FeCrO_4$	iron (II) chromate