Learning Guide

Subject Code	Chem 1	General Inorganic Chemistry
Module Code	2.0	Chemical Reactions and Stoichiometry
Lesson Code	2.1.1	Writing and Naming Chemical Formulas Part 1
Time Limit		30 min

Components	**Tasks**	**AT**[a]	**ATA**[b]
Target	By the end of the chapter, the students must be able to name and write chemical formulas.	1 min	
Hook	*"What's in a name? That which we call a rose by any other name would smell as sweet." – William Shakespeare* One's name definitely holds a strong feeling, a great significance and above all, identity to its owner. It adds up to the main essence of everyone's existence. In the same way, all sorts of things get to avail this gift. Take our product labels as examples. They are often printed plainly outside their containers – a necessary information for us to know, in a way, their uses and importance. Rummage through your stuff at home and identify what substance(s) is/are being described in each item: 1. You experienced a sour-smelling sneeze when your mum poured a liquid in a pot of *adobo* as she stirred it in a counter-clockwise direction. 2. A plate of small white tangy-tasting crystals was left on the table. This will go best with your green mangoes. 3. A TV personality uploaded a cake recipe. You noticed that she added a cupful of white powder into the mixture. After some time, the dough started to rise. 4. You were doing the dishes last night *(yay!)*, when you noticed that reddish-brown coatings started to form on the sides of your metal spoons. 5. As one of the Wednesday cleaners, you were tasked to remove the toilet stains. You carried a very powerful chemical with you and treated it with great caution and respect. Probably, your answers were mostly their common names. As we go through this chapter, we will be naming chemical substances systematically based on their chemical formulas.	3 min	
Ignite	When you go to the grocery store you probably see several products proclaiming themselves to be 'organic.' While the agriculture industry has made their own distinction between what they define as organic or inorganic, chemistry would actually classify all food as organic. Chemical compounds are classified into two – organic and inorganic. The distinction between these two groups isn't clearly defined, but generally *organic compounds* are substances that are consist of carbon atoms, while *inorganic compounds* do not. There are a few significant exceptions to this rule. Say, carbon dioxide and carbon monoxide. Organic compounds can also be distinguished as molecules that comprise all living things (plants, proteins, fats, DNA) while inorganic compounds constitute non-living things (salts,	16 min	

metals, and other related compounds).

Chemical formulas are shorthand symbols for compounds. They are made from symbols of their elements in a pattern that shows by atoms present in the compound (Bayquen, 2012).

Types of Formulas:

1. The *empirical formula* (also called the *simplest formula*) of a compound reflects the simplest ratio of the atoms in the compound.

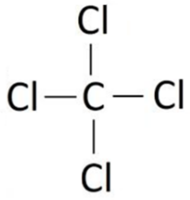
   Glucose, CH_2O

2. The *molecular formula* of a compound is based on the actual number of atoms that comprise a molecule of that compound.

   Glucose, $C_6H_{12}O_6$

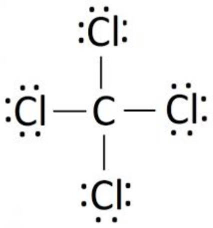
3. A *structural formula* consists of symbols to represent atoms and lines or bonds to represent valence.

   Carbon tetrafluoride

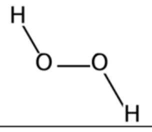
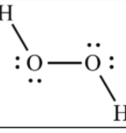
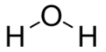
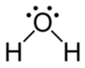
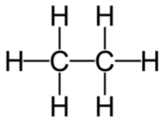
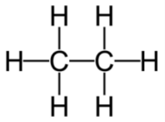


4. The *Lewis electron dot formula* shows the distribution of electrons in the outermost shell of the atom as the atoms are united to each other. Here, bonds of unshared electrons are shown.

   Carbon tetrafluoride



Examples:

Chemical Compound	Empirical Formula	Molecular Formula	Structural Formula	Lewis Electron Dot Formula
hydrogen peroxide	HO	H_2O_2		
water	H_2O	H_2O		
ethane	CH_3	CH_3CH_3		

Binary Compounds Containing a Metal and a Nonmetal

Binary compounds are made up of two elements. These are formed when metals and nonmetals are combined resulting in compounds usually ionic in nature. Recall that metals are located on the leftward of the periodic table, and the nonmetals are on the rightward. The metalloids or the semimetals lie along a diagonal line separating the metals and nonmetals.

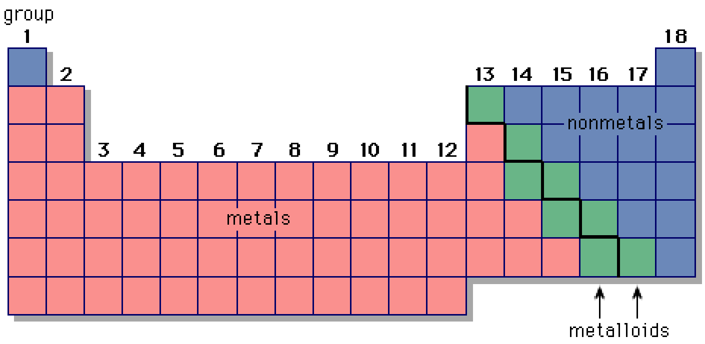


Fig. 1. *Position of metals, nonmetals, and metalloids in the periodic table.* (n.d.). Retrieved July 27, 2020 from Britannica.

Cations (positively-charged ions) and *anions* (negatively-charged ions) are produced when a metal gives off electrons, and a nonmetal obtains those electrons. In writing the right formula of ionic compounds, the ionic charges of the cations and anions must be known. These can be easily brought to mind by knowing the position of the elements in the periodic table.

There is a hasty technique to identify the charges of ions and this is simply by looking to the group numbers of the metals. Monatomic ions, ions consisting of exactly one electron, of elements in the same main group have the same ionic charge.

Examples:

- Alkali metals: Li, Na, K, Rb, Cs, and Fr (1+ charge)
- Halogens—F, Cl, Br, and I (1- charge)

1A	**2A**	**3A**	**4A**	**5A**	**6A**	**7A**
H^- Hydride						
Li^+ Lithium	Be^{2+} Beryllium		C^{4-} Carbide	N^{3-} Nitride	O^{2-} Oxide	F^- Fluoride
Na^+ Sodium	Mg^{2+} Magnesium	Al^{3+} Aluminum		P^{3-} Phosphide	S^{2-} Sulfide	Cl^- Chloride
K^+ Potassium	Ca^{2+} Calcium				Se^{2-} Selenide	Br^- Bromide
Rb^+ Rubidium	Sr^{2+} Strontium				Te^{2-} Telluride	I^- Iodide
Cs^+ Cesium	Ba^{2+} Barium					

Fig. 2. Monoatomic Ions of the Representative Elements

For cations, ion charge is equal to the A-group number. For example, potassium (K) is in Group 1A and forms K^+, calcium (Ca) is in Group 2A and forms Ca^{2+}. For anions, ion charge is equal to A-group number minus 8; for example, oxygen (O) is in Group 6A (6-8=-2) and thus forms O^{2-}.

The number 8 was used to indicate the total number of electrons that the outer shell of an element needs to be filled in order to attain stability. This is known as the *Octet Rule* and will be discussed next quarter.

Guidelines for Binary Ionic Compounds

1. In all ionic compounds, the names and formulas will be composed of the cation (positive ion) first followed by the anion (negative ion).
2. For all binary ionic compounds, you will be using the name of the metal to name the cation. The suffix *-ide* added to the root of the name of the nonmetal will be the name of the anion.

For example, the anion formed from chlorine is named chloride (chlor+*ide*). Therefore, the compound formed from the metal sodium and the nonmetal chlorine is named sodium chloride (Silberberg, 2015).

Table 1. Common Monoatomic Ions

Charge	Formula	Name
Cations		
1+	H^+	hydrogen
	Li^+	lithium
	Na^+	sodium
	K^+	potassium
	Cs^+	cesium
	Ag^+	silver
	Mg^{2+}	Magnesium
2+	Ca^{2+}	Calcium
	Sr^{2+}	Strontium
	Ba^{2+}	Barium
	Zn^{2+}	Zinc
	Cd^{2+}	Cadmium
	Al^{3+}	Aluminum
Anions		
1-	H^-	Hydride
	F^-	Fluoride
	Cl^-	Chloride
	Br^-	Bromide
	I^-	Iodide
2-	O^{2-}	Oxide
	S^{2-}	Sulfide
3-	N^{3-}	Nitride

Subscripts are used in formulas when atom ratios are not 1:1. The subscript 1 is never used because just writing a symbol means that you are taking at least one of it (Bayquen, 2012).

Examples:

1. Write the formula for strontium fluoride.
   Solution:
   First, write the symbols for the ions. Note that Sr is a

metal that lost two electrons forming a cation, while F is a nonmetal that acquired an electron forming an anion.

$Sr^{2+} \quad F^{-}$

Then, crisscross the charges and write them as subscripts.

$Sr^{2+} \quad F^{-}$

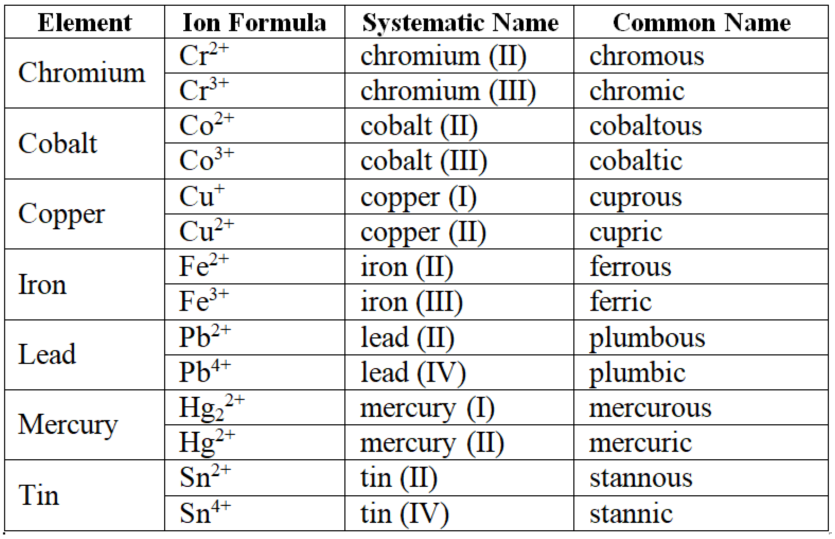
Rewrite the formula dropping the charges.
The formula for strontium fluoride is SrF_2.
A subscript 1 is not written anymore.

2. Determine the formula for calcium sulfide.
   Solution:
   The symbols for the ions are:
   $Ca^{2+} \quad S^{2-}$
   Crisscross the charges.
   $Ca^{2+} \quad S^{2-}$
   Dropping the charges, you get
   Ca_2S_2
   Such subscripts are always reduced to lowest terms, hence the correct formula for calcium sulfide is CaS (Mendoza and Religioso, 2001).

Many metals can form more than one ion, particularly the transition elements (B groups). A Roman numeral within parentheses immediately after the metal ion's name is essential in naming compounds containing these elements to indicate its ionic charge. Cobalt can form two compounds with chlorine:

- $CoCl_2$, named cobalt (II) chloride (spoken "cobalt two chloride"), which contains Co^{2+}; and
- $CoCl_3$, named cobalt (III) chloride, which contains Co^{3+}.

Table 2. Some Metals that Form More than One Ion



Element	**Ion Formula**	**Systematic Name**	**Common Name**
Chromium	Cr^{2+}	chromium (II)	chromous
	Cr^{3+}	chromium (III)	chromic
Cobalt	Co^{2+}	cobalt (II)	cobaltous
	Co^{3+}	cobalt (III)	cobaltic
Copper	Cu^{+}	copper (I)	cuprous
	Cu^{2+}	copper (II)	cupric
Iron	Fe^{2+}	iron (II)	ferrous
	Fe^{3+}	iron (III)	ferric
Lead	Pb^{2+}	lead (II)	plumbous
	Pb^{4+}	lead (IV)	plumbic
Mercury	Hg_2^{2+}	mercury (I)	mercurous
	Hg^{2+}	mercury (II)	mercuric
Tin	Sn^{2+}	tin (II)	stannous
	Sn^{4+}	tin (IV)	stannic

Our main focus here is on the use of systematic names, but some common (trivial) names are still applied. We will be using the Latin root of the metal followed by either of two suffixes in naming common names for particular metal ions.

- The suffix -*ous*, for the ion with the lower charge
- The suffix -*ic*, for the ion with the higher charge

Thus, iron (II) chloride is also called ferrous chloride and iron (III) chloride is ferric chloride. Memory aid: there is an "o" in -*ous* and lower, and an "i" in -*ic* and higher (Silberberg, 2015).

Examples:

Ions	Formula	Systematic Name
Fe^{2+} and Cl^-	$FeCl_2$	iron (II) chloride
Sn^{4+} and F^-	SnF_4	tin (IV) fluoride
Cu^{2+} and O^{2-}	CuO	copper (II) oxide
Pb^{2+} and I^-	PbI_2	lead (II) iodide
Hg^{2+} and Br^-	$HgBr_2$	mercury (II) bromide

<u>Compounds that Contain Polyatomic Ions</u>

Polyatomic compounds are formed in the same way as binary compounds. A *polyatomic ion* is a stable group of atoms that carries an overall electrical charge. These atoms are being bonded together by covalent bonds. One or more atoms in the group carry a positive or negative charge. Therefore, the group as a whole has an ionic charge (Mendoza and Religioso, 2001).

$$\text{Sodium hydroxide, } \underbrace{Na}_{\text{monoatomic ion, } Na^+}\underbrace{OH}_{\text{polyatomic ion, } OH^-}$$

$$\text{Iron (II) perchlorate, } \underbrace{Fe}_{\text{monoatomic ion, } Fe^{2+}}\underbrace{(ClO_4)_2}_{\text{polyatomic ion, } ClO_4^-}$$

$$\text{Ammonium sulfate, } \underbrace{(NH_4)_2}_{\text{polyatomic ion, } NH_4^+}\underbrace{SO_4}_{\text{polyatomic ion, } SO_4^{2-}}$$

These polyatomic ions form ionic bonds in the same manner as the simple ions. Keep in mind that the polyatomic ion stays together as a charged unit.

- The formula for ammonium sulfate is $(NH_4)_2SO_4$: two NH_4^+ balances one SO_4^{2-}.
- The formula for copper (II) carbonate is $CuCO_3$: one Cu^{2+} balances one CO_3^{2-}.

The polyatomic ion appears in parentheses with the subscript written outside when two or more of the same polyatomic ions are present in the formula unit.

For example, calcium chlorite contains one Ca^{2+} and two ClO_2^- ions and has the formula $Ca(ClO_2)_2$. Parentheses and a subscript are only used if more than one of a given polyatomic ion is present; thus, copper (I) chlorate is $CuClO_3$, not $Cu(ClO_3)$ (Silberberg, 2015).

Table 3. Common Polyatomic Ions

Name	**Formula**	**Name**	**Formula**
Ammonium	NH_4^+	Acetate	$C_2H_3O_2^-$
Nitrite	NO_2^-	Cyanide	CN^-
Nitrate	NO_3^-	Chromite	CrO_2^-
Hypochlorite	ClO^-	Sulfite	SO_2^{2-}
Chlorite	ClO_2^-	Sulfate	SO_3^{2-}
Chlorate	ClO_3^-	Carbonate	CO_3^{2-}
Perchlorate	ClO_4^-	Chromate	CrO_4^{2-}
Hydroxide	OH^-	Dichromate	$Cr_2O_7^{2-}$
Bicarbonate	HCO_3^-	Phosphate	PO_4^{3-}

Many polyatomic ions in which an element is bonded to one or more oxygen atoms. These are known as oxoanions or oxyanions. Several families of oxoanions will be encountered in Chemistry that differ only in the number of oxygen atoms. The following naming rules are applied with these ions.

With two oxoanions in the family:

- The ion with more O atoms takes the nonmetal root and the suffix -*ate*.
- The ion with fewer O atoms takes the nonmetal root and the suffix -*ite*.

For example, SO_4^{2-} is the sulfate ion, and SO_3^{2-} is the sulfite ion; similarly, NO_3^- is nitrate, and NO_2^- is nitrite (Silberberg, 2015).

With four oxoanions in the family:

- The ion with most O atoms has the prefix *per*-, the nonmetal root, and the suffix -*ate*.
- The ion with one fewer O atom has just the root and the suffix -*ate*.
- The ion with two fewer O atoms has just the root and the suffix -*ite*.
- The ion with least (three fewer) O atoms has the prefix *hypo*-, the root, and the suffix -*ite* (Silberberg, 2015).

For example, for the four chlorine oxoanions,

- ClO_4^- is perchlorate
- ClO_3^- is chlorate
- ClO_2^- is chlorite
- ClO^- is hypochlorite

Examples:

1. Determine the formula of magnesium hydroxide.
   Solution:
   The ions are

   $$Mg^{2+} \quad OH^-$$

   Do the crisscrossing.

   $$\begin{tikzcd} Mg^{2+} \arrow[r, bend right] & OH^- \arrow[l, bend left] \end{tikzcd}$$

   The total positive and negative charges must be equal. Placing the hydroxide ion in the parentheses, the correct formula is $Mg(OH)_2$.

2. Write the correct formula for strontium bicarbonate.
   Solution:
   The ions are

   $$Sr^{2+} \quad HCO_3^-$$

   Then, crisscross the charges.

   $$Sr^{2+} \quad HCO_3^-$$

   Correct formula will be $Sr(HCO_3)_2$. The bicarbonate ion is inside the parentheses because a multiple of that ion is necessary.

3. Name the following compounds:
   a. $Ca(ClO)_2$
   b. $FePO_4$
   c. $SrCO_3$

   Answers:
   a. calcium hypochlorite
   b. iron (III) phosphate or ferric phosphate
   c. strontium carbonate

4. Give the correct formula of the following compounds base on their names.
   a. sodium acetate
   b. ammonium bicarbonate
   c. magnesium phosphate

   Answers:
   a. $NaC_2H_3O_2$
   b. NH_4HCO_3
   c. $Mg_3(PO_4)_2$

How to Speak Chemistrian: Naming Chemical Compounds
Watch https://youtu.be/mlRhLicNo8Q

A number of chemicals are commonly found, staring blankly at you whenever you placed your gaze upon your cupboards and cabinets, at home. Mason jars, hollow bottles, paper boxes, and even tin cans are some of the containers that bear its identity for the end-user to easily identify its nature and uses. These typical household chemicals are intended particularly to assist general hygiene purposes, pest control, domestic cleaning, and sometimes in cooking. Take a look at the following products:

1. Sodium bicarbonate ($NaHCO_3$) or baking soda is used in cleaning, deodorizing, leavening, buffering, and fire extinguishing.
2. Magnesium hydroxide ($MgOH$) or milk of magnesia is used as an antacid and a laxative.
3. Sodium chloride ($NaCl$) or table salt is composed of white crystals used as food seasoning and preservative.
4. Sodium hydroxide ($NaOH$) or caustic soda is an alkaline substance mainly used in soap-making. It is the primary ingredient in drain and oven cleaners.
5. Calcium carbonate ($CaCO_3$) or limestone is a white crystalline solid that is one of the most common natural substances. Sources include chalk, limestone, marble, animal

shells, bones. It is used as antacids, paint, cement, toothpaste.

Navigate

8 min

CHEM-MUST-TRY! ***(Non-Graded Evaluation)***

I. Fill in the following table with the formulas of the compounds by combining each cation with each anion. The formula of aluminum nitrate is provided as an example.

	Cl^-	**NO_3^-**	**SO_4^{2-}**	**PO_4^{3-}**
H^+				
Ag^+				
Ba^{2+}				
Al^{3+}		$Al(NO_3)_3$		
NH_4^+				

II. Write the formula for each of the following compounds.

1. Potassium nitrate
2. Zinc phosphate
3. Cuprous sulfide
4. Lead (II) acetate
5. Sodium perchlorate

III. Name the following compounds.

1. $KMnO_4$
2. Mg_3N_4
3. BeO
4. $LiC_2H_3O_2$
5. AlAs

Additional Assessment ***(Graded Evaluation)*****:**

I. State why the formula or chemical name at the end of each statement is incorrect. Leave the item blank if you see it as correct (Silberberg, 2015).

1. Ammonium phosphate is $(NH_3)_4PO_4$.
2. Aluminum hydroxide is $AlOH_3$.
3. $Mg(HCO_3)_2$ is manganese (II) carbonate.
4. $Cr(NO_3)_3$ is chromic (III) nitride.
5. $Ca(NO_2)_2$ is cadmium nitrate.

II. Name the following compounds from the chemical formula.

1. $AgNO_3$
2. $Ca_3(PO_4)_2$
3. $KClO_3$
4. $(NH_4)_2Cr_2O_7$
5. GaN

	III. Write the chemical formula for the following compounds. 1. Tin (IV) oxide 2. Copper (II) nitrate 3. Chromium (VI) cyanide 4. Manganese (IV) nitride 5. Tin (II) sulfite		
Knot	**SUMMARY:** • Chemical compounds are divided into two groups – organic and inorganic. Chemical formulas are shorthand symbols for compounds. They are made from the symbols of their elements in a pattern that shows the ratios of atoms present in the compound. • Guidelines for writing and naming binary ionic compounds. 1. The cation is always listed before the anion. 2. The ratio is always expressed by the smallest whole numbers. 3. The uncharged English name of the metal is used. This is only applicable for monoatomic ions that only have one charge. 4. In the stock method, chemical formulas involving metals with ions forming more than one charge use Roman numerals in parenthesis after the metal ion. 5. In the classical method, take note that the name of the metal ion that has a lower charge uses the suffix *-ous* while that with a higher charge ends in *-ic*. 6. If the symbol of the element is derived from a Latin word, the Latin root is generally used rather than the English root. 7. In naming anions, the suffix *-ide* will be attached to its English root. • Suffixes, and sometimes prefixes, are being used indicate the number of oxygen atoms of oxoanions. • Treat polyatomic ions as single units, rather than trying to balance the atoms individually. Put parentheses around the polyatomic ion before writing the subscript.	2 min	

[a] suggested time allocation set by the teacher

[b] actual time spent by the student (for information purposes only)

References:

Albarico, J. (PSHS-CBRZ). (n.d.). THINK Framework. Based on Science Links by E.G. Ramos and N. Apolinario, Quezon City. Rex Bookstore.

Bayquen, A. (2012). *Chemistry, Exploring Life Through Science*. (G. Bernas PhD, Coordinator.) 2nd Edition. Quezon City, Philippines: Phoenix Publishing House.

Comparing Inorganic & Organic Compounds: Explanation and Practice. (n.d.). Retrieved July 26, 2020 from Alberta Education Diploma – Chemistry 30: ExamPrep and Study Guide.

Mendoza, E., Religioso T. (2001). *You and the Natural World Series, Third Year Chemistry Textbook*. (M. Deauna, Coordinator.) 2nd Edition. Quezon City, Philippines: Phoenix Publishing House.

Silberberg M. (2015). *Chemistry: The Molecular Nature of Matter and Change*. 7th Edition. New York, USA: McGraw-Hill Education.

Prepared by: Jezreel A. Gaa
Position: Special Science Teacher (SST) – I
Campus: MIMAROPA Region

Reviewed by: Princess Ann B. Digneneng
Position: Special Science Teacher (SST) – II
Campus: CENTRAL LUZON