

Nomenclature Independent Unit Part 1

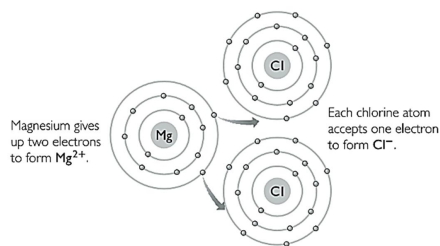
Definitions (some old, some new):

- **Ion**=an atom that has an unequal number of protons and electrons.
 - **Cations** are **positively** charged ions
 - **Anions** are **negatively** charged ions
- **Compound**=a substance that has **2 or more** different types of **elements** bonded together
- **Bond**= a region that forms when **electrons from different atoms interact with each other**. The attraction between 2 or more atoms allows for the formation of a compound.
 - Only **valence electrons** participate in bonding
- **Octet Rule**
 - Atoms bond in order to get **8 valence electrons** around them (**Exceptions: H, Li**)

Ionic Compounds:

- Made up of a **metal** and a **nonmetal**
- **Electrons** are **transferred** from the **metal** to the **nonmetal**
- Even though the compound is made up of 2 or more charged ions, the compound overall has **no charge**
 - This means that the total charge of the **cations** + total charge of **anions** = 0

Magnesium Chloride



1. Consider the compound made up of Mg and Cl represented by the chemical formula $MgCl_2$
 - a. How many Mg atoms make up the compound?
 - b. How many Cl atoms make up the compound?
 - c. For Mg
 - i. Is it a metal or nonmetal?
 - ii. Will it lose or gain electrons to form an ion?
 - iii. Will it form a cation or anion?
 - iv. What is the charge on a Mg ion?
 - d. For Cl (chlorine):
 - i. Is it a metal or nonmetal?
 - ii. Will it lose or gain electrons to form an ion?
 - iii. Will it form a cation or anion?
 - iv. What is the charge on a Cl ion?
- e. Explain how the overall charge on the compound $MgCl_2$ is 0.

When working in chemistry, it is often convenient to write a chemical in symbols. For example we might write down the substance table salt as NaCl. In talking about chemistry however, it is a bit tacky to say “en-ay see-ell” when we want to refer to a substance. Also, in formal writing we should use the name of the compound rather than its symbols. Therefore we need to learn how to say the proper names of ionic substances.

Model 1 – Ion Charges for Selected Elements

1	H ⁺												
2	Li ⁺	Be ²⁺							N ³⁻	O ²⁻	F ⁻		
3	Na ⁺	Mg ²⁺	Transition elements				Al ³⁺		P ³⁻	S ²⁻	Cl ⁻		
4	K ⁺	Ca ²⁺	Fe ²⁺ Fe ³⁺	Ni ²⁺ Ni ³⁺	Cu ⁺ Cu ²⁺	Zn ²⁺						Br ⁻	
5	Rb ⁺	Sr ²⁺			Ag ¹⁺			Sn ²⁺ Sn ⁴⁺				I ⁻	
6		Ba ²⁺				Hg ₂ ²⁺ Hg ²⁺		Pb ²⁺ Pb ⁴⁺					

←———— Cations —————→ ←———— Anions —————→

1. Based on the information in Model 1
 - a. Identify three elements in the table that form only one type of cation.
 - b. Identify three elements in the table that form only one type of anion.
 - c. Identify three elements in the table that form more than one type of cation.
 - d. In what region of the periodic table are these “multiple cation” elements usually located?
2. Consider the ions of potassium (K) and sulfur (S). Write chemical formulas for all possible ionic compounds involving these ions, using the simplest ratio(s) of potassium (K) and sulfur (S). Keep in mind that the **sum of the charges** in an ionic compound **must equal zero**.
3. Consider the ions of iron (Fe) and sulfur (S). Write chemical formulas for all possible ionic compounds involving these ions, using the simplest ratio(s) of iron (Fe) and sulfur (S). Keep in mind that the **sum of the charges** in an ionic compound **must equal zero**.

Model 2 – Ionic Compound Names (Metals that form one ion)

NaCl	Sodium chloride	Zn ₃ P ₂	Zinc phosphide
CaS	Calcium sulfide	Al ₂ O ₃	Aluminum oxide
Ag ₂ S	Silver sulfide	SrCl ₂	Strontium chloride

- Circle the symbol for the metal in each of the compounds in Model 2.
- Which element comes first in the name and formula of the compounds in Model 2—the metal or the nonmetal?
- Use the table of ions in **Model 1** to answer the following questions:
 - In the compound zinc phosphide, what is the charge on the zinc ion?
 - In the compound zinc phosphide, what is the charge on the phosphide ion?
- Explain why a 3 to 2 ratio of ions is necessary for the compound zinc phosphide.
- Is there anything in the name “zinc phosphide” that indicates there are three zinc and two phosphorus ions in the formula unit?
- Is there any other ratio of zinc and phosphorus ions that could exist? For instance, could you have Zn₂P or ZnP₂? Explain your answer.
- Explain why you don’t need to specify the number of ions in the compound when you are naming ionic substances like those in Model 2.
- Model 2 is labeled “Metals that form one ion.” What other metals that also form only one ion could be included in the Model 2 list? Model 1 may be helpful in this regard.
- Describe how the names of the nonmetal elements in Model 2 are changed when they are in their anion forms.

- Name the following ionic compounds using what you learned from Model 2.

Li₂O MgF₂ Al₂S₃ K₃N

- Provide the chemical formula for each of the following ionic compounds.

Barium chloride Magnesium oxide

- Consider the two chemical formulas you wrote in Question 3 for compounds of iron and sulfur. Would the name “iron sulfide” be sufficient to uniquely identify either of those compounds? Explain.

Read This!

When the metal in an ionic compound always forms an ion with the same charge, you need not indicate that charge as part of the compound name. However, some atoms have the ability to form more than one type of ion. This can make naming confusing. You can’t simply refer to a compound of copper and oxygen as “copper oxide.” People won’t know which compound you are referring to—CuO or Cu₂O.

Model 3 – Ionic Compound Names (Metals that form multiple ions)

Cu ₂ O	Copper(I) oxide	PbO	Lead(II) oxide
CuO	Copper(II) oxide	PbO ₂	Lead(IV) oxide
SnF ₂	Tin(II) fluoride	FeCl ₂	Iron(II) chloride
SnF ₄	Tin(IV) fluoride	FeCl ₃	Iron(III) chloride

- Model 3 is labeled “Metals that form multiple ions.” What other metals that form multiple ions could be included in Model 3? Model 1 may be helpful in this regard.
- Describe the most obvious difference between the names in Model 3 and those in Model 2.
- Keeping in mind that subscripts after a symbol indicate the number of atoms, use the chemical formulas in Model 3 to answer the following questions:
 - Identify the number of copper cations in copper(I) oxide and copper(II) oxide, respectively.
 - Identify the number of iron cations in iron(II) chloride and iron(III) chloride, respectively.

19. Keeping in mind that the sum of the charges in an ionic compound must equal zero, use the chemical formulas in Model 3 to answer the following questions:
- Identify the charge on the copper cations in copper(I) oxide and copper(II) oxide, respectively.
 - Identify the charge on the iron cations in iron(II) chloride and iron(III) chloride, respectively.

20. What do the Roman numerals in the compounds described in Question 19 indicate?

21. Fill in the table below using what you've learned from Model 3.




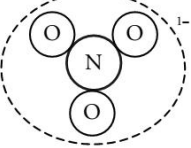
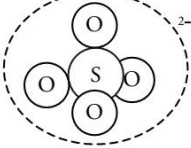
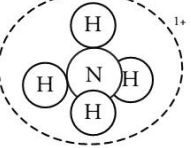
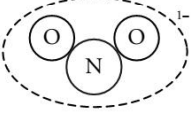
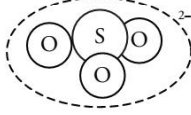

Compound	Charge on Cation	Name of the Compound
PbCl_4	Pb^{4+}	Lead(IV) chloride
Fe_2O_3		
SnO		
CuBr_2		

22. For each of the compounds in the table below, determine the type of metal in the compound and then name the compound using the correct naming method.

	Metal forms only one ion	Metal forms multiple ions	Name
CaBr_2			
MgO			
Ag_3N			
SnCl_2			
CuF_2			
K_3P			
Zn_3N_2			
HgO			

Do you know you eat a lot of "-ates"? Next time you look at a food label, read the ingredients and you will likely find a number of ingredients that end with "-ate," such as sodium phosphate or calcium carbonate. Did you ever wonder what the chemical formulas of these ingredients look like? In this activity we will explore polyatomic ions, which are groups of atoms that carry a charge. These ions are found in our food ingredients, natural waterways, and many other chemical compounds you encounter every day.

Model 1 – Types of Ions

Monatomic Ions	Nitride 	Sulfide 	Chloride 
Polyatomic Ions	Nitrate 	Sulfate 	Ammonium 
	Nitrite 	Sulfite 	Hydroxide 

1. Use Model 1 to complete the table below.

Name of Ion	Nitride	Nitrate	Sulfate	Sulfite	Ammonium
Charge on Ion		-1			
Type and Number of Atoms			1 sulfur 4 oxygen		
Chemical Formula				SO_3^{2-}	

2. Consider the terms “monatomic” and “polyatomic” as they are used in Model 1. Write a definition for each of these terms. It may be helpful to break the words apart (*i.e.*, poly – atomic).

Monatomic—

Polyatomic—

3. What types of elements (metals or nonmetals) are shown in the polyatomic ions in Model 1?
4. The net charge on a sulfide ion (S^{2-}) is -2 . Explain how this ion obtains its charge. Your answer should include a discussion of subatomic particles (protons, neutrons, and/or electrons).

The dotted line around each polyatomic ion in Model 1 shows that the group of atoms has a charge. The charge is not on any one atom, but rather on the group of atoms as a whole.

5. The “chlorate” polyatomic ion has a charge of -1 and is composed of one chlorine atom (the central atom) and three oxygen atoms.
- Draw a model of a chlorate ion.
 - Write the chemical formula for the chlorate ion, including its charge.
6. Compare the “nitrate” and “nitrite” as well as “sulfate” and “sulfite” in model 1. Based on the pattern, determine what “chlorite” would look like.
- Draw a model of a chlorite ion.
 - Write the chemical formula for the chlorite ion, including its charge.

Model 2 – Common Polyatomic Ions

1+		1-		2-		3-	
ammonium	NH_4^{1+}	acetate	CH_3COO^{1-}	sulfate	SO_4^{2-}	phosphate	PO_4^{3-}
		hydroxide	OH^{1-}	sulfite	SO_3^{2-}		
		nitrate	NO_3^{1-}	carbonate	CO_3^{2-}		
		nitrite	NO_2^{1-}	chromate	CrO_4^{2-}		
		bicarbonate	HCO_3^{1-}	dichromate	$Cr_2O_7^{2-}$		
		permanganate	MnO_4^{1-}				
		perchlorate	ClO_4^{1-}				
		chlorate	ClO_3^{1-}				
		chlorite	ClO_2^{1-}				
		hypochlorite	ClO^{1-}				

*****Note: You must memorize all the boxed polyatomic ions!*****

7. What is the only polyatomic ion that is a cation?
8. Bromine forms polyatomic ions with structures similar to those of chlorine. Using the chlorine family of polyatomic ions as a model, predict the name of the BrO_4^{1-} ion.
9. Underline the polyatomic ion in each of these ionic compounds. Write out the name and formula of the ions including their charges.
- $CaCO_3$
 - $Mg(OH)_2$
 - NH_4Cl

Model 3 – Ternary Ionic Compounds

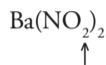
Compound Name	Ion Symbols and Charges		Chemical Formula
Ammonium phosphate	NH_4^{1+}	PO_4^{3-}	$(NH_4)_3PO_4$
Barium nitrite	Ba^{2+}	NO_2^{1-}	$Ba(NO_2)_2$
Ammonium sulfate	NH_4^{1+}	SO_4^{2-}	$(NH_4)_2SO_4$
Aluminum carbonate	Al^{3+}	CO_3^{2-}	$Al_2(CO_3)_3$
Iron(III) hydroxide	Fe^{3+}	OH^{1-}	$Fe(OH)_3$
Potassium nitrate	K^{1+}	NO_3^{1-}	KNO_3

10. Consider the compound iron(III) hydroxide in Model 3.

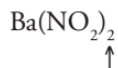
- How many hydroxide ions (OH^{1-}) are combined with an iron(III) ion (Fe^{3+})?
- Is your answer to part *a* the only combination of iron(III) and hydroxide that should exist in nature? Explain.

11. Consider the compound barium nitrite in Model 3.

- What does the subscripted "2" *inside* the parentheses of the chemical formula tell you about the compound?



- What does the subscripted "2" *outside* the parentheses of the chemical formula tell you about the compound?



12. A student writes the chemical formula for the ionic compound calcium hydroxide as CaOH_2 .

- Write the chemical formula for each ion in the compound.

Calcium: Hydroxide:

- Why is the student's chemical formula for the compound calcium hydroxide wrong?

13. Write chemical formulas for the following ternary ionic compounds. Include parentheses when appropriate.

- Calcium sulfate
- Copper(II) nitrate
- Lithium phosphate
- Potassium permanganate
- Aluminum sulfite
- Magnesium bicarbonate

14. Name the following ternary ionic compounds.

- BaSO_4
- NH_4NO_3
- $\text{K}_2\text{Cr}_2\text{O}_7$
- $\text{Fe}(\text{NO}_3)_3$
- $\text{Mg}(\text{CH}_3\text{COO})_2$
- $\text{Al}_2(\text{CO}_3)_3$

IONIC COMPOUNDS: ALL

I. Simple Binary Compounds

Name of Ionic Compound	Chemical Formula of Ionic Compound
Potassium Iodide	
Calcium Fluoride	
Lithium Sulfide	
Aluminum Oxide	

II. Ionic Compounds Containing a Polyatomic Ion:

Name of Ionic Compound	Chemical Formula of Ionic Compound
Calcium carbonate	
Magnesium nitrate	
Aluminum sulfate	
Ammonium chloride	
Cesium chlorate	
Potassium sulfate	
Barium acetate	
	KCH_3CO_2
	$\text{Mg}_3(\text{PO}_4)_2$
	$\text{Al}(\text{ClO}_3)_3$
	CaSO_4
	$\text{Sr}(\text{HCO}_3)_2$
	Li_2CO_3
	$\text{Ba}(\text{NO}_3)_2$
	NH_4OH

III. Ionic Compounds containing Transition Metals

Name of Ionic Compound	Chemical Formula of Ionic Compound
Copper (II) sulfate	
Copper (I) oxide	
Cobalt (II) hydroxide	
Iron (III) acetate	
Lead (IV) sulfate	
	FeCl_2
	PbSO_3
	$\text{Co}_2(\text{CO}_3)_3$
	CuClO_3
	$\text{Cr}(\text{OH})_3$

Review of the Mole Concept

How to Convert from Grams to Moles

1. Determine the mass of your substance that you are interested in
2. If necessary, calculate the molar mass for that substance. If it is given, use that value.

Sample problem:

"How many moles of KCl are in 26.0 grams of KCl?"

$$1 \times 39.1 + 1 \times 35.5 = 74.6 \text{ grams/1 mole KCl}$$

3. Use dimensional analysis to solve for moles.

$$26.0 \text{ grams KCl} \times \frac{1 \text{ mole KCl}}{74.6 \text{ grams KCl}}$$

$$= \frac{26.0 \times 1 \text{ mole KCl}}{74.6} \\ = 0.349 \text{ moles KCl}$$

How to Convert from Moles to Grams

1. Determine the # of moles of your substance that you are interested in
2. If necessary, calculate the molar mass for that substance. If it is given, use that value.

Sample problem:

"How many grams of CO₂ are in 1.5 moles of CO₂?"

$$1 \times 12.0 + 2 \times 16.0 = 44.0 \text{ grams/1 mole CO}_2$$

3. Use dimensional analysis to solve for mass.

$$1.5 \text{ moles CO}_2 \times \frac{44.0 \text{ grams CO}_2}{1 \text{ mole CO}_2}$$

$$= \frac{1.5 \times 44.0 \text{ g}}{1} \\ = 66.0 \text{ grams CO}_2$$

How to Determine the Number of Molecules or Atoms in a Sample

1. Determine the given amount of your substance and what you're looking for
2. If necessary, calculate the gram formula mass for that substance. If the GFM is given, use that value.

Sample Problem:

"How many molecules of CO₂ are in 66.0 grams of CO₂?"

"How many atoms of oxygen are in 66.0 grams of CO₂?"

$$1 \times 12.0 + 2 \times 16.0$$

$$= 44.0 \text{ grams/1 mole CO}_2$$

3. Use dimensional analysis to solve for molecules.

$$66.0 \text{ grams CO}_2 \times \frac{1 \text{ mole CO}_2}{44.0 \text{ grams CO}_2} \times \frac{6.02 \times 10^{23} \text{ molecules CO}_2}{1 \text{ mole CO}_2} \\ = 9.03 \times 10^{23} \text{ molecules CO}_2$$

Mole Concept Review: SHOW WORK!

Note: you must determine the chemical formula and molar mass of the compound based on the given name

1. What is the mass of 2.5 moles of Magnesium Chloride? _____

2. How many moles are contained in 180 grams of Potassium Sulfate? _____

3. How many grams are in 3.2 moles of Sodium Fluoride? _____

4. How many moles are in 78.3 grams of Aluminum Nitride? _____

5. How many molecules are there in 450 grams of Lithium Oxide? _____

6. How many grams are there in 7.5×10^{23} molecules of Copper (II) Iodide? _____