

TEACHER

# Naming Molecular Compounds

How are the chemical formula and name of a molecular compound related?

## Why?

When you began chemistry class this year, you probably already knew that the chemical formula for carbon dioxide was  $\text{CO}_2$ . Today you will find out why  $\text{CO}_2$  is named that way. Naming chemical compounds correctly is of paramount importance. The slight difference between the names carbon monoxide ( $\text{CO}$ , a poisonous, deadly gas) and carbon dioxide ( $\text{CO}_2$ , a greenhouse gas that we exhale when we breathe out) can be the difference between life and death! In this activity you will learn the naming system for molecular compounds.

## Model 1 – Molecular Compounds

Molecular Formula	Number of Atoms of First Element	Number of Atoms of Second Element	Name of Compound
$\text{ClF}$	1	1	Chlorine monofluoride
$\text{ClF}_5$	1	5	Chlorine pentafluoride
$\text{CO}$	1	1	Carbon monoxide
$\text{CO}_2$	1	2	Carbon dioxide
$\text{Cl}_2\text{O}$	2	1	Dichlorine monoxide
$\text{PCl}_5$	1	5	Phosphorus pentachloride
$\text{N}_2\text{O}_5$	2	5	Dinitrogen pentoxide

- Fill in the table to indicate the number of atoms of each type in the molecular formula.  
*See Model 1.*
- Examine the molecular formulas given in Model 1 for various molecular compounds.
  - How many different *elements* are present in each compound shown?  
*Two.*
  - Do the compounds combine metals with metals, metals with nonmetals, or nonmetals with nonmetals?  
*Nonmetals are combined with nonmetals in the molecular compounds shown.*
  - Based on your answer to *b*, what type of bonding must be involved in molecular compounds?  
*Covalent.*
- Find all of the compounds in Model 1 that have chlorine and fluorine in them. Explain why the name "chlorine fluoride" is not sufficient to identify a specific compound.  
*There are two compounds with chlorine and fluorine. The name "chlorine fluoride" does not indicate which compound it refers to. It could be the one with one fluorine atom, or the one with five fluorine atoms.*
- Assuming that the name of the compound gives a clue to its molecular formula, predict how many atoms each of these prefixes indicates, and provide two examples.
 

mono-	one	Carbon monoxide or chlorine monofluoride.
di-	two	Carbon dioxide or dinitrogen pentoxide.
penta-	five	Chlorine pentafluoride or phosphorus pentachloride.

## Model 2 – Prefixes and Suffixes

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

Molecular Formula	Name of Compound
$\text{BCl}_3$	Boron trichloride
$\text{SF}_6$	Sulfur hexafluoride
$\text{IF}_7$	Iodine heptafluoride
$\text{NI}_3$	Nitrogen triiodide
$\text{N}_2\text{O}_4$	Dinitrogen tetroxide
$\text{Cl}_2\text{O}$	Dichlorine monoxide
$\text{P}_4\text{O}_{10}$	Tetraphosphorus decoxide
$\text{B}_5\text{H}_9$	Pentaboron nonahydride
$\text{Br}_3\text{O}_8$	Tribromine octoxide
$\text{ClF}$	Chlorine monofluoride

5. Examine the prefixes in Model 2. Fill in the numerical value that corresponds to each prefix.

*See Model 2.*

6. What suffix (ending) do all the compound names in Model 2 have in common?

*-ide.*



7. Carefully examine the names of the compounds in Model 2. When is a prefix NOT used in front of the name of an element?

*The prefix mono- is not used when there is only one atom of the element that appears first in the formula.*

8. Consider the compound NO.

- a. Which element, nitrogen or oxygen, would require a prefix in the molecule name? Explain your answer.

*The element O would require a prefix (mono-). The element N would not. A prefix is not used when there is one atom of the element that appears first in the formula, but it is used to indicate the number of atoms of each element in a molecule at all other times.*

- b. Name the molecule NO.

*Nitrogen monoxide.*



9. Find two compounds in Model 2 that contain a subscript of “4” in their molecular formula.

- a. List the formulas and names for the two compounds.

*$\text{N}_2\text{O}_4$ , dinitrogen tetroxide,  $\text{P}_4\text{O}_{10}$ , tetraphosphorus decoxide.*

- b. What is different about the spelling of the prefix meaning “four” in these two names?

*One of the names cuts off the “a” in tetra-, while the other one uses the whole prefix.*

10. Find two compounds in Model 2 that contain the prefix “mono-” in their names.

a. List the formulas and names for the two compounds.

*ClF, chlorine monofluoride, and Cl<sub>2</sub>O, dichlorine monoxide.*

b. What is different about the spelling of the prefix meaning “one” in these two names?

*One of the names cuts off the last “o” in mono-, while the other one uses the whole prefix.*

11. Identify any remaining names of compounds in Model 2 where the prefixes that do not exactly match the spelling shown in the prefix table.

*Tetraphosphorus decoxide and tribromine octoxide.*

12. Use your answers to Questions 9–11 to write a guideline for how and when to modify a prefix name for a molecular compound. Come to a consensus within your group.

*A guideline is that if the prefix ends in a vowel (a or o) and the element begins with a vowel (o), the vowel is removed from the prefix. If the name “sounds better” without the repetition of vowels, then the vowel in the prefix typically gets dropped.*

13. Would the guideline you wrote for Question 12 give you the correct name for NI<sub>3</sub> as it is given in Model 2? If not, modify your guideline to include this example.

*Nitrogen triiodide shows that it is not just “any” vowel repetition that results in cutting short the prefix. It appears that final “a’s” or “o’s” get dropped from a prefix if it precedes an element beginning with “o.”*

14. All of the compounds listed in Model 2 are binary molecular compounds. Compounds such as CH<sub>3</sub>OH or PF<sub>2</sub>Cl<sub>3</sub> are not binary, and compounds such as NaCl or CaCl<sub>2</sub> are not molecular. Propose a definition for “binary molecular compounds.”

*Binary molecular compounds contain two nonmetallic elements.*



15. Collaborate with your group members to write a list of rules for recognizing and naming binary molecular compounds from their chemical formulas.

1. *Binary molecular compounds can be recognized because they contain only two elements that are both nonmetals (or a metalloid with a nonmetal).*

2. *In front of the name of the first element, write the prefix that corresponds with the subscript for that element, **unless** there is only one atom of the first element. In that case, write the name of the first element (no prefix).*

3. *In front of the name of the second element, write the prefix that corresponds with the subscript for that element. Then write the name of the second element.*

4. *Remove the ending from the name of the second element and replace it with the suffix -ide.*

5. *If a prefix ends in either an “a” or “o,” and the name of the element begins with an “o,” drop the final vowel from the prefix.*



16. For each of the following compounds, indicate whether or not your naming rules from Question 15 will apply. If not, explain why the naming rules do not apply.



*Fe is a metal. The rules do not apply since it is not a molecular compound.*



*Yes, the rules apply.*



*The rules do not apply—this compound is not binary.*

17. Using the rules your group developed in Question 15, name each of the following molecular compounds.

Molecular Formula	Molecule Name
$\text{PBr}_3$	<i>Phosphorus tribromide</i>
$\text{SCl}_4$	<i>Sulfur tetrachloride</i>
$\text{N}_2\text{F}_2$	<i>Dinitrogen difluoride</i>
$\text{SO}_3$	<i>Sulfur trioxide</i>
$\text{BrF}$	<i>Bromine monofluoride</i>

18. Write molecular formulas for the following compounds.

Molecular Formula	Molecule Name
$\text{S}_2\text{F}_{10}$	Disulfur decafluoride
$\text{CCl}_4$	Carbon tetrachloride
$\text{OF}_2$	Oxygen difluoride
$\text{N}_2\text{O}_3$	Dinitrogen trioxide
$\text{P}_4\text{S}_7$	Tetraphosphorus heptasulfide



## Extension Questions

19. This activity focused on molecular (covalent) compounds, while an earlier activity addressed ionic compounds. Notice that the formulas for both types of compounds can look very similar, even though their names are quite different:

Chemical Formula	Type of Compound/Bonding	Compound Name
MgF <sub>2</sub>	Ionic	Magnesium fluoride
CuF <sub>2</sub>	Ionic	Copper(II) fluoride
SF <sub>2</sub>	Molecular (covalent)	Sulfur difluoride
NaBr	Ionic	Sodium bromide
AuBr	Ionic	Gold(I) bromide
IBr	Molecular (covalent)	Iodine monobromide

Identify two differences between the names or formulas for ionic compounds versus those for binary molecular compounds. Also identify two similarities.

	Names and Formulas of Ionic Compounds	Names and Formulas of Molecular (Covalent) Compounds
Differences	<ul style="list-style-type: none"> <li>• Contain metals and nonmetals.</li> <li>• No prefixes are used in naming, but sometimes Roman numerals are used (for transition metals with variable charges).</li> <li>• In writing formulas, charges must be taken into account.</li> </ul>	<ul style="list-style-type: none"> <li>• Contain nonmetals with nonmetals.</li> <li>• Prefixes are used in naming.</li> <li>• Charges do not need to be considered when writing formulas.</li> </ul>
Similarities	<ul style="list-style-type: none"> <li>• Contain only two elements (binary).</li> <li>• -ide ending for second element (nonmetal).</li> <li>• The more highly electronegative element (more "nonmetallic") is always placed second.</li> </ul>	

20. Use complete sentences to explain why AlCl<sub>3</sub> is called "aluminum chloride" (no prefix required), but BCl<sub>3</sub> is called "boron trichloride."

*Aluminum chloride is an ionic compound. It is understood that the empirical formula must contain a 1:3 ratio of ions because the ion charges are +3 for aluminum and -1 for chloride. Boron trichloride is a molecular (covalent) compound, which is named using a prefix system.*

21. In the table below, first identify the type of bonding present in each compound. Then fill in the missing name or formula for each compound using the appropriate set of rules.

Chemical Formula	Type of Compound/Bonding	Compound Name
$CS_2$	<i>Molecular (covalent)</i>	<i>Carbon disulfide</i>
$PbI_2$	<i>Ionic</i>	<i>Lead(II) iodide</i>
$BaCl_2$	<i>Ionic</i>	<i>Barium chloride</i>
$Se_2S_6$	<i>Molecular (covalent)</i>	<i>Diselenium hexasulfide</i>
$XeF_4$	<i>Molecular (covalent)</i>	Xenon tetrafluoride
$Na_3P$	<i>Ionic</i>	Sodium phosphide
$N_2O_5$	<i>Molecular (covalent)</i>	Dinitrogen pentoxide
$CoBr_3$	<i>Ionic</i>	Cobalt(III) bromide

# Teacher Resources – Naming Molecular Compounds

## Learning Objectives

1. Name binary molecular compounds based on their chemical formulas.
2. Write chemical formulas for binary molecular compounds based on their names.
3. Distinguish binary molecular compounds from other types of compounds, such as ionic compounds or more complex molecular compounds.

## Prerequisites

1. Students should have prior knowledge of chemical symbols and element names.
2. Students should be familiar with the periodic table and the general location of metals and nonmetals in the table.
3. Students should be familiar with ionic and covalent bonding.
4. For the extension, students need to know how to name ionic compounds, including those containing metals with variable charges.

## Assessment Questions

1. What is the correct name for  $\text{PCl}_3$ ?
  - a. Monophosphorus tetrachloride
  - b. Phosphorus trichloride
  - c. Phosphorus tetrachloride
  - d. Monophosphorus trichloride
2. What is the correct formula for tetraphosphorus decoxide?
  - a.  $\text{P}_2\text{O}_5$
  - b.  $\text{P}_3\text{O}_{10}$
  - c.  $\text{P}_4\text{O}_{10}$
  - d.  $\text{P}_5\text{O}_{10}$
3. Why is CO named carbon monoxide rather than monocarbon monoxide?

## Assessment Target Responses

1. *b.*
2. *c.*
3. *When naming a covalent compound that contains one atom of each type of element, the prefix mono-, meaning one, is used. However, the element that appears first in the compound's formula does not typically get the prefix mono-. Thus, the word "oxide" is preceded by "mono," but "carbon" has no prefix.*

## Teacher Tips

- While this activity could be used before or after naming ionic compounds, it would be most effective if it were completed after the students have learned to name ionic compounds. The extension, in particular, encourages students to put their new knowledge in the context of what they have learned before. Students find it easy to name compounds when they are told what the type is, but they find it challenging when ionic and covalent compounds are presented to them at the same time.
- In the extension, the students are also encouraged to make a bridge in their thinking between the term “molecular,” which is most often used in describing compounds, and “covalent,” which is usually used in describing bond types. For the purposes of this activity, students can consider the terms synonymous. Molecular compounds always contain covalent bonding, although covalent bonding can also be found in network solids and some ionic compounds with polyatomic ions.
- Encourage students to develop a habit of classifying the type of compound, ionic or molecular, before they try to name a compound. The student success rate tends to go up remarkably by just labeling “I” or “M” before they attempt the name.
- In Question 12, students are asked to write a general guideline concerning how prefixes may be modified in naming a compound. Literature sources vary widely on this topic.