Name:
Period:
Date:

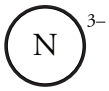
Polyatomic Ions

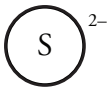
Can a group of atoms have a charge?

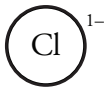
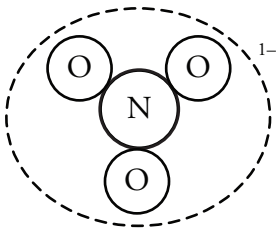
Why?

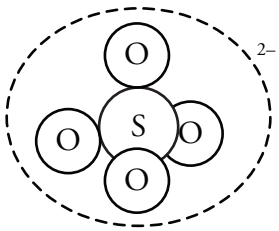
Do you know you eat a lot of "-ates"? Next time you look at a food label, read the ingredients and you will likely find a number of ingredients that end with "-ate," such as sodium phosphate or calcium carbonate. Did you ever wonder what the chemical formulas of these ingredients look like? In this activity 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.

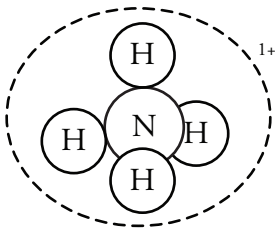
Model 1 – Types of Ions

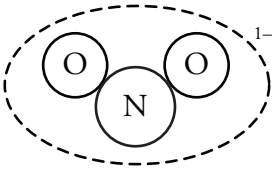
<table>
<tr><td>Monatomic Ions</td><td>Nitride
 

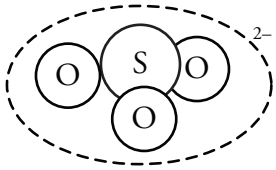
Sulfide
 

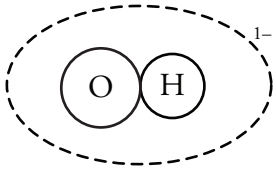
Chloride
 
</td></tr>
<tr><td>Polyatomic Ions</td><td>Nitrate
 

Sulfate
 

Ammonium
 

Nitrite
 

Sulfite
 

Hydroxide
 
</td></tr>
</table>

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). Make sure your group comes to consensus.

   Monatomic—

   Polyatomic—

3. What types of elements (metals or nonmetals) are shown in the polyatomic ions in Model 1?

4. What type of bonds (ionic or covalent) hold the atoms together in polyatomic ions? Explain your reasoning.

5. 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 electrons)*.

6. 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. Based on your knowledge of monatomic ions, propose an explanation for the net charge on a polyatomic ion. Your answer should include a discussion of subatomic particles.

7. What are the similarities and differences between the nitrate and nitrite ions in Model 1?

8. What are the similarities and differences between the sulfate and sulfite ions in Model 1?

9. The "chlorate" polyatomic ion has a charge of –1 and is composed of one chlorine atom (the central atom) and three oxygen atoms.

   a. Draw a model of a chlorate ion.

b. Write the chemical formula for the chlorate ion, including its charge.

10. In your group discuss what "chlorite" would look like.

a. Draw a model of a chlorite ion.

b. 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-}				

11. What is the only polyatomic ion that is a cation?

12. How are bicarbonate and carbonate related?

14. How are chromate and dichromate related?

15. Identify the polyatomic ion in each of these ionic compounds. Write out the name and formula of polyatomic ion including its charge.

a. $CaCO_3$ *b.* $Mg(OH)_2$ *c.* 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

16. How are ternary ionic compounds in Model 3 different from binary ionic compounds (NaCl, MgO, $CaBr_2$, etc.) that you've seen previously? *Hint:* Consider the meaning of the word "**bi**nary."

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

a. How many hydroxide ions (OH^{1-}) are combined with an iron(III) ion (Fe^{3+})?

b. Is your answer to part *a* the only combination of iron(III) and hydroxide that should exist in nature? Explain.

18. Consider the compound barium nitrite in Model 3.

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

$$Ba(NO_2)_2$$

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

$$Ba(NO_2)_2$$

19. How many atoms of each element are in one formula unit of ammonium phosphate, $(NH_4)_3PO_4$?

nitrogen hydrogen phosphorus oxygen

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

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

Calcium: Hydroxide:

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

21. Many of the chemical formulas in Model 3 include parentheses. Which one of the following rules summarizes the appropriate use of parentheses in ternary ionic compounds? For the three rules that do not apply in all cases, show at least one counter example from the chemical formulas in Model 3.

Parentheses are used around any ion that is used more than once in a formula unit.

Parentheses are used around any polyatomic ion.

Parentheses are used around any polyatomic ion used more than once in a formula unit.

Parentheses are only used around polyatomic anions used more than once in a formula unit.

22. Write chemical formulas for the following ternary ionic compounds.

a. Calcium sulfate *b.* Copper(II) nitrate *c.* Lithium phosphate

d. Potassium permanganate *e.* Aluminum sulfite *f.* Magnesium bicarbonate

23. Name the following ternary ionic compounds.

a. $BaSO_4$ *b.* NH_4NO_3 *c.* $K_2Cr_2O_7$

d. $Fe(NO_3)_3$ *e.* $Mg(C_2H_3O_2)_2$ *f.* $Al_2(CO_3)_3$