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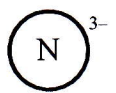
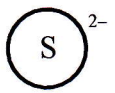
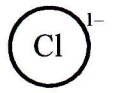
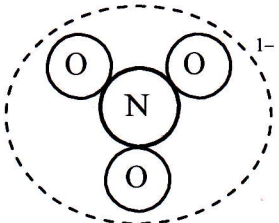
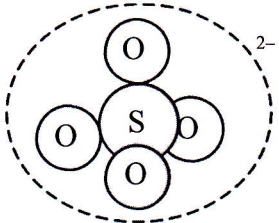
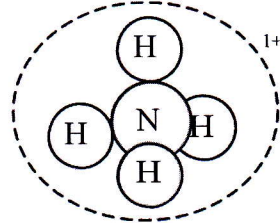
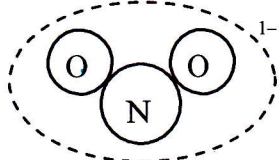
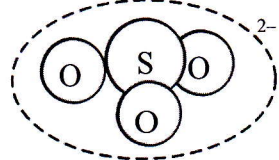
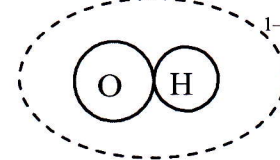
Polyatomic Ions

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

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	-3	-1	-2	-2	+1
Type and Number of Atoms	3 nitrogen nitride	1 nitrogen nitrate 3 oxygen	1 sulfur 4 oxygen	1 sulfur 3 oxygen	1 nitrogen 4 hydrogen
Chemical Formula	N^{3-}	NO_3^{1-}	SO_4^{2-}	SO_3^{2-}	NH_4^{1+}

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— made up of one atom

Polyatomic— made up of more than one atom; many atoms

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

nonmetals

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

covalent; covalent bonds hold two nonmetals together

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.

sulfur contains 16 protons (atomic number) and a neutral atom would contain 16 electrons. The final (valence) shell would need 2 more electrons to have a full shell, increasing the number of electrons to 18. 16 positive charges + 18 negative = -2

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.

Polyatomic ions are bound together by covalent bonds which is a sharing of electrons, so if the overall count of electrons is more than the overall protons, you will have a negative charge

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

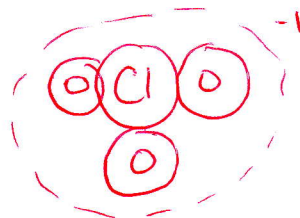
↳ both made up of nitrogen and oxygen atoms; same charge (-1)
↳ nitrate has 3 oxygens; nitrite has 2

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

↳ both made up of sulfur and oxygen atoms; same charge (-2)
↳ sulphate has 4 oxygens, sulfite has 3

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.

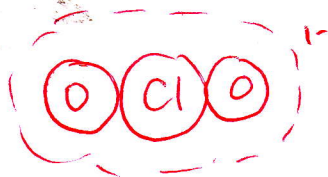


b. Write the chemical formula for the chlorate ion, including its charge.

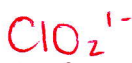


10. In your group discuss what "chlorite" would look like.

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	$\text{CH}_3\text{COO}^{1-}$	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	$\text{Cr}_2\text{O}_7^{2-}$		
		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?

both contain CO_3

13. Predict the chemical formula and charge for the bisulfate ion.



14. How are chromate and dichromate related?

both contain Cr and O

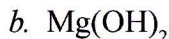
15. Bromine forms polyatomic ions with structures similar to those of chlorine. Using the chlorine family of polyatomic ions as a model, predict the name of the BrO_4^{1-} ion.

perbromate

16. Identify the polyatomic ion in each of these ionic compounds. Write out the name and formula of the ions including their charges.



calcium carbonate
 Ca^{+2} CO_3^{2-}



magnesium hydroxide
 Mg^{2+} OH^{-1}



ammonium chloride
~~ammonium chloride~~
 NH_4^+ Cl^-



Model 3 – Ternary Ionic Compounds

Compound Name	Ion Symbols and Charges		Chemical Formula
Ammonium phosphate	NH_4^{1+}	PO_4^{3-}	$(\text{NH}_4)_3\text{PO}_4$
Barium nitrite	Ba^{2+}	NO_2^{1-}	$\text{Ba}(\text{NO}_2)_2$
Ammonium sulfate	NH_4^{1+}	SO_4^{2-}	$(\text{NH}_4)_2\text{SO}_4$
Aluminum carbonate	Al^{3+}	CO_3^{2-}	$\text{Al}_2(\text{CO}_3)_3$
Iron(III) hydroxide	Fe^{3+}	OH^{1-}	$\text{Fe}(\text{OH})_3$
Potassium nitrate	K^{1+}	NO_3^{1-}	KNO_3

17. 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 "binary."

They have more than two types of elements



18. 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+})?

$\text{Fe}(\text{OH})_3$ 3 OH^{-1}

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

Yes. Fe has a combining capacity of 3 and OH has a combining capacity of 1. Only 3 OH could fit. No more, no less.

19. 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?

$\text{Ba}(\text{NO}_2)_2$
 ↑
 there are 2 oxygens

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



20. How many atoms of each element are in one formula unit of ammonium phosphate, (NH₄)₃PO₄?

nitrogen	hydrogen	phosphorus	oxygen
3	12	1	4

21. A student writes the chemical formula for the ionic compound calcium hydroxide as CaOH₂.

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



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

- forgot brackets around hydroxide
- subscript "2" outside of brackets

22. 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.

~~True~~ False ex. Al₂(CO₃)₃

Parentheses are used around any polyatomic ion.

False ex. KNO₃ ← polyatomic

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

True

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

False ex. (NH₄)₃PO₄

23. 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



24. Name the following ternary ionic compounds.



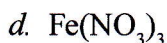
barium sulfate



ammonium nitrate



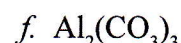
potassium dichromate



iron (III) nitrate



magnesium acetate



aluminum carbonate

Extension Questions

25. If you were asked to go to the chemical storage area and retrieve a bottle of "sulfate," could you do so? Explain. (Assume you have permission from your teacher to go into the storage area.)

You can find bottles of compounds or aqueous solutions containing sulphate but not on its own. Sulphate is unstable and reactive on its own and must be combined with a cation such as CaSO_4 .

26. When asked to classify sodium acetate (NaCH_3COO) as either an ionic or covalent compound, a student responded with, "Sodium acetate is both ionic and covalent." Explain why the student gave this answer.

The Na^+ and CH_3COO^- are bound together by an ionic bond but the polyatomic ion, CH_3COO^- is held together by covalent bonds as all the atoms in CH_3COO^- are nonmetals. CH_3COO^- acts as a single nonmetal in the ionic bond with the metal Na^+ .