**Chemical Bonding POGIL**

**Activity 1 – A compound by any other name...**

**Objective:**
- Based on the elements present in a chemical formula, classify the compound as ionic or covalent (covalent molecules are also referred to as molecular compounds).

**Getting Started:**
Review the definitions for an element and a compound.

**The Model:**
- Fe is the elemental form of iron.
- C is the elemental form of carbon.
- Cl₂ is the elemental form of chlorine.
- FeCl₃ is a compound formed from the elements iron and chlorine

**Reviewing the Model**

1. What does the subscript 2 indicate in Cl₂?
2. What is implied when there is no subscript?
3. Classify C, Fe and Cl as metals or nonmetals.

**Exploring the Model**

4. Evaluate the statement, “The formulas for elements never contain a subscript.” Is this statement true?
5. From the two examples provided, would you expect the formula S₈ to represent a compound to an element?
6. Using examples from the Model, explain how you classified S₈.
Exercising Your Knowledge

7. Classify each formula below as an element or a compound:
   a. Co ______________________
   b. CaCl₂ ______________________
   c. CsOH ______________________
   d. Br₂ ______________________
   e. NaBr ______________________
   f. SiO₂ ______________________
   g. PF₅ ______________________
   h. P₄ ______________________
   i. OF₂ ______________________

Summarizing Your Thoughts

8. What clues are given in chemical formulas that allow you to differentiate between an element and a compound?

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**Chemical Bonding POGIL**

**Activity 2 – Types of bonds...**

**Getting Started:**
There are two major classes of compounds typically encountered as part of an introductory course: ionic and covalent compounds. The concepts describing how these compounds are held together can be developed as you progress through your studies. However, before you get to those concepts you must be able to quickly classify a compound into one class or the other. In other words, your ability to classify compounds will guide how you will think about bigger ideas.

**The Model:**
Table 1 – Compounds that are considered...

<table>
<thead>
<tr>
<th>Ionic</th>
<th>Covalent</th>
</tr>
</thead>
<tbody>
<tr>
<td>ZnCl₂</td>
<td>CCl₄</td>
</tr>
<tr>
<td>Na₂O</td>
<td>P₂O₅</td>
</tr>
<tr>
<td>Fe₂O₃</td>
<td>N₂O₄</td>
</tr>
<tr>
<td>CuI</td>
<td>NI₃</td>
</tr>
</tbody>
</table>

**Reviewing the Model**

1. The compound ZnCl₂ is considered to be a (an) ___________________________ compound.

2. The compound that contains nitrogen and oxygen is a (an) ___________________________ compound.
Exploring the Model
3. Does the classification seem to be made based on how many atoms of each element are represented in the formula?

4. Write the symbols for the elements presented by the Model (Table 1) near their correct location on the outline of the periodic table.

5. Compare the types of elements found (metals or nonmetals) for the two classes of compounds. Do you see any trend in the type of elements present and the classification?

Exercising Your Knowledge
6. Classify each of the following as either ionic or covalent.
   a. NaBr __________________
   b. SF$_6$ __________________
   c. CoBr$_2$ ________________
   d. OF$_2$ ________________
   e. NO$_2$ ________________
   f. BaS __________________
   g. CsF$_2$ ________________
   h. CrCl$_3$ ________________
   i. CO$_2$ ________________
   j. CO ________________

Summarizing Your Thoughts
7. Write a simple rule that will allow you to classify compounds as ionic or covalent on the basis of what you have learned from the Model.
Chemical Bonding POGIL

Activity 3 – What’s in a name?

Objective:
• Identify some simple rules about nomenclature (naming).

The Model:
Examine the table below, and answer the following questions.

<table>
<thead>
<tr>
<th>Cation</th>
<th>Anion</th>
<th>Chemical Formula</th>
<th>Compound Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Na⁺</td>
<td>Cl⁻</td>
<td>NaCl</td>
<td>sodium chloride</td>
</tr>
<tr>
<td>Ca²⁺</td>
<td>O²⁻</td>
<td>CaO</td>
<td>calcium oxide</td>
</tr>
<tr>
<td>Zn²⁺</td>
<td>Cl⁻</td>
<td>ZnCl₂</td>
<td>zinc chloride</td>
</tr>
<tr>
<td>Li⁺</td>
<td>S²⁻</td>
<td>Li₂S</td>
<td>lithium sulfide</td>
</tr>
<tr>
<td>K⁺</td>
<td>N³⁻</td>
<td>K₃N</td>
<td>potassium nitride</td>
</tr>
</tbody>
</table>

Reviewing the Model

1. Are ALL cations positive ions or negative ions?
2. Are ALL anions positive ions or negative ions?
3. What is the name of the compound formed by the combination of Li⁺ and S²⁻ ions?

Exploring the Model

4. When the name of an ionic compound is given, which ion is stated first?
5. Compare the first part of the compound name to the name of the element from the periodic table. How does the name of the cation correspond to the name of the element?

6. Compare the second part of the compound name to the name of the element from the periodic table. How does the name of the anion correspond to the name of the element?

7. From what part of the periodic table do the cations in the Model come (metals or nonmetals)?

8. From what part of the periodic table do the anions in the Model come?
**Exercising Your Knowledge**

9. For each of the following, predict whether the ion will likely be a cation or an anion.
   a. Magnesium ion
   b. Selenide ion
   c. Bromide ion
   d. Cesium ion

10. For each ionic compound, identify the cation and the anion.
   a. Sodium fluoride
   b. Strontium sulfide
   c. Lithium iodide
   d. Barium chloride

11. In what way did the name provide clues about the classification of each element as a cation or anion?

12. Where on the periodic table would you expect to find elements that ionize to form cations?

13. Where on the periodic table would you expect to find elements that ionize to form anions?

**Summarizing Your Thoughts**

14. Consider the clues you identified, and write a general rule for how you change the name of elements to cations when naming ionic compounds.

15. Consider the clues you identified, and write a general rule for how you change the name of elements to anions when naming ionic compounds.
16. Given the chemical formula of an ionic compound, list at least three necessary steps to give the correct name of that compound. (If needed, use a chemical formula of a compound from the table above as an example in listing the naming steps.)

**Chemical Bonding POGIL**

*Activity 4 – Predicting the correct chemical formula for ionic compounds formed from simple anions*

**Objective:**
- To learn how to predict the correct number of cations and anions in a simple salt.

**The Model:**

<table>
<thead>
<tr>
<th>Cation</th>
<th>Anion</th>
<th>Chemical Formula</th>
<th>Compound Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Na⁺</td>
<td>Cl⁻</td>
<td>NaCl</td>
<td>sodium chloride</td>
</tr>
<tr>
<td>Zn²⁺</td>
<td>Cl⁻</td>
<td>ZnCl₂</td>
<td>zinc chloride</td>
</tr>
<tr>
<td>Na⁺</td>
<td>S²⁻</td>
<td>Na₂S</td>
<td>sodium sulfide</td>
</tr>
<tr>
<td>K⁺</td>
<td>N³⁻</td>
<td>K₃N</td>
<td>potassium nitride</td>
</tr>
</tbody>
</table>

**Reviewing the Model**

1. What is the charge on the zinc ion?
2. What is the charge on the nitride ion?
3. What is the charge on the chloride ion?
4. What is the charge on the ionic compound, sodium chloride?
5. What is the charge on the ionic compound, sodium sulfide?
6. How many potassium ions are present in K₃N?
7. What does the “2” stand for in the formula for ZnCl₂?

**Exploring the Model**

8. Sodium chloride is NaCl, and zinc chloride ZnCl₂. Why are there more chloride ions in the zinc compound?

9. Sodium chloride is NaCl, and sodium sulfide is Na₂S. Why are there more sodium ions in the sulfide compound?
Exercising Your Knowledge

10. How many chloride ions would combine with an Al$^{3+}$ ion to form aluminum chloride?

11. What charge does the barium ion possess in the compound BaCl$_2$?

Summarizing Your Thoughts

12. Explain how you determined the number of chloride ions needed in aluminum chloride.

13. From Table 3 and the answers above, what do you know about the overall charge on ALL ionic compounds?

14. List at least three necessary steps to obtain the correct chemical formula of any simple ionic compound.

**Chemical Bonding POGIL**

**Activity 5 — When the Romans march through...**

**Objective:**
- Understand how to write the chemical formula of an ionic compound containing metals with varying oxidation states.

**Getting Started:**
When a Group IA metal forms a cation, it will always form a +1 cation. When a Group IIA metal forms a cation, it will always form a +2 charge. However, as we progress into the transition metals we find that these metals can form cations with different charges under different circumstances. Use the Model below to develop some rules that describe how to communicate the charge of the cation.
The Model:
Examine the table below, and answer the following questions.

<table>
<thead>
<tr>
<th>Chemical Formula</th>
<th>Chemical Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>FeBr₂</td>
<td>iron (II) bromide</td>
</tr>
<tr>
<td>FeBr₃</td>
<td>iron (III) bromide</td>
</tr>
<tr>
<td>PbO</td>
<td>lead (II) oxide</td>
</tr>
<tr>
<td>PbO₂</td>
<td>lead (IV) oxide</td>
</tr>
<tr>
<td>Cu₃N</td>
<td>copper (I) nitride</td>
</tr>
<tr>
<td>Cu₃N₂</td>
<td>copper (II) nitride</td>
</tr>
</tbody>
</table>

Reviewing the Model
1. What is the expected charge on the bromide ion?
2. What is the expected charge on the oxide ion?
3. What is the expected charge on the nitride ion?
4. Represent the Roman numeral II as an Arabic numeral.
5. Represent the Roman numeral III as an Arabic numeral.
6. Represent the Roman numeral IV as an Arabic numeral.
7. What two elements are present in the compounds in the last two rows of Table 4?
8. What is different about the chemical formulas of these last two compounds in Table 4?
9. What is different about the compound names of these last two compounds in Table 4?

Exploring the Model
10. Use your rules that you developed in Activity 4 to determine the charge on the iron ion in these compounds:
    a. Charge on iron in FeBr₂
    b. Charge on iron in FeBr₃
11. How is the Roman numeral in the compound name related to the charge on the iron atoms?
12. Does this hold true for all of the compounds in Table 4.

13. What types of metals require the use of a Roman numeral in the name of their ionic compounds?

14. Where are these metals located on the periodic table?

**Exercising Your Knowledge**

15. Why do the compounds in this activity require Roman numerals in the name while compounds such as calcium chloride do not?

16. If only the chemical formula were given for the compounds in the above examples, how could you determine the amount of charge on the cation?

17. Complete the table that follows with the proper ions, chemical formulas and compound names. The first row of the table has been completed for you.

<table>
<thead>
<tr>
<th>Cation</th>
<th>Anion</th>
<th>Chemical Formula</th>
<th>Compound Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Na⁺</td>
<td>Cl⁻</td>
<td>NaCl</td>
<td>sodium chloride</td>
</tr>
<tr>
<td>Ba²⁺</td>
<td>I⁻</td>
<td>BaI₂</td>
<td></td>
</tr>
<tr>
<td>Mn³⁺</td>
<td>O²⁻</td>
<td>MnO</td>
<td>manganese (II) oxide</td>
</tr>
<tr>
<td>Mg²⁺</td>
<td>N³⁻</td>
<td>Mg(N₃)₂</td>
<td>cobalt (III) fluoride</td>
</tr>
<tr>
<td></td>
<td></td>
<td>CrO</td>
<td></td>
</tr>
<tr>
<td>Cu⁺</td>
<td>S²⁻</td>
<td>Cu₂S</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ca₃P₂</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>SnS₂</td>
<td></td>
</tr>
</tbody>
</table>
18. How will you know when to use a Roman numeral when writing the name of an ionic compound?

19. Look at your answers from Activity 4 that lists the steps necessary to give the correct name of an ionic compound from its chemical formula. How do the steps differ when ions with varying oxidation states are involved?

20. Look at your answer from Activity 5 that lists the steps necessary to give the correct chemical formula of an ionic compound given its name. How do the steps differ when ions of varying charges are involved?

Chemical Bonding POGIL

Activity 6 – Poly wanna ion?

Objective:
- Recognize the names of poly atomic ions and understand how to write the chemical formulas of ionic compounds containing polyatomic ions.

Getting Started:
Thus far we have considered only simple, monatomic cations and anions. There is another class of ions that are often called polyatomic ions. Polyatomic ions are a group of atoms that are held together by covalent interactions, the entire group of atoms carries the charge. The most common polyatomic ions contain oxygen. Their names may not seem to make sense now, but there is a system to this madness. It is your task to study the Model and determine what the nomenclature rules are.

The Model:
Table 6

<table>
<thead>
<tr>
<th>Ion</th>
<th>Name</th>
<th>Ion</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>N⁻³</td>
<td>nitride</td>
<td>S²⁻</td>
<td>sulfide</td>
</tr>
<tr>
<td>NO₂⁻</td>
<td>nitrite</td>
<td>SO₃²⁻</td>
<td>sulfite</td>
</tr>
<tr>
<td>NO₃⁻</td>
<td>nitrate</td>
<td>SO₄²⁻</td>
<td>sulfate</td>
</tr>
</tbody>
</table>
**Reviewing the Model**

1. What element is associated with the prefix “nitr-”? 
2. What element is associated with the prefix “sulf-”? 
3. What is the ending (suffix) when there are no oxygen atoms in the formula? 
4. What suffixes are used when oxygen is included in the formula? 

**Exploring the Model**

5. Does the suffix of each name depend on the charge of the ion? 
6. Does the suffix tell you how many oxygen atoms there are? 
7. Compare nitrate to nitrite. Which ion has more oxygen atoms? 
8. Compare sulfate to sulfite. Which ion has more oxygen atoms? 

**Exercising Your Knowledge**

9. Consider the two oxo- ions of chlorine, ClO$_2^-$ and ClO$_3^-$. Which ion would have the –ate ending?  
   a. Write the names of these two oxo- ions of chlorine. 

10. Consider the two oxo- ions of phosphorus, PO$_3^{3-}$ and PO$_4^{3-}$. Which ion would have the –ate ending?  
    a. Write the names of these two oxo- ions of phosphorus. 

11. In the movie *Star Wars Episode V: The Empire Strikes Back*, the character Han Solo is frozen in the fictional material, carbonite. If carbonite existed, what would be its likely chemical formula?

12. Why would it be unlikely for a solid material to be made entirely of pure carbonite ions?
Summarizing Your Thoughts

13. The last three letters of a name can tell you a lot about a particle! For each of the name endings below, give a general description of what type of ion or particle would be expected to have that ending (cation, monatomic anion, polyatomic anion, metal element, and/or nonmetal element).

a. –ide ___________________________  

b. –ium ___________________________  

c. –ate ___________________________  

d. –ine ___________________________  

e. –ite ___________________________

Chemical Bonding POGIL

Activity 7 – A Mixed Up Activity...

Getting Started:
Now that we have introduced polyatomic ions, we have to consider how this new affects the name of a compound and how we write the chemical formula. There are new features in this Model; let’s see is we can figure out how to handle them.

The Model:
Table 7 – All types of ionic compounds

<table>
<thead>
<tr>
<th>Chemical Formula</th>
<th>Compound Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>CaSO₄</td>
<td>calcium sulfate</td>
</tr>
<tr>
<td>CaSO₃</td>
<td>calcium sulfite</td>
</tr>
<tr>
<td>Na₂PO₄</td>
<td>sodium phosphate</td>
</tr>
<tr>
<td>Li₂CO₃</td>
<td>lithium carbonate</td>
</tr>
<tr>
<td>NH₄Cl</td>
<td>ammonium chloride</td>
</tr>
<tr>
<td>Be(NO₂)₂</td>
<td>beryllium nitrite</td>
</tr>
<tr>
<td>Mg₃(PO₃)₂</td>
<td>magnesium phosphite</td>
</tr>
<tr>
<td>Fe(NO₃)₃</td>
<td>iron (III) nitrate</td>
</tr>
<tr>
<td>Al(OH)₃</td>
<td>aluminum hydroxide</td>
</tr>
</tbody>
</table>

Reviewing the Model

1. Write the name and the symbol for all of the monatomic ions in the Model (Table 7).

2. Write the name and formula (including the charge) for all the polyatomic ions in the Model (Table 7).

3. The ammonium cation is the only polyatomic cation in the Model. What are the formula and charge of the ammonia cation?
4. How many nitrite ions are present in beryllium nitrite?

5. What new typesetting feature is used in these chemical formulas?

**Exploring the Model**

6. Do all polyatomic ions require the use of parenthesis?

7. When are parenthesis used?

8. Have the nomenclature rules you established earlier in activities changes? If so, how? If not, is that important to know?

9. How many nitrogen atoms are in beryllium nitrite?

10. Describe the thought process you used to determine the number of nitrogen atoms in beryllium nitrite.

11. How many oxygen atoms are in beryllium nitrite?

12. In what way does determining the number of oxygen atoms differ from the process you just described for nitrogen?

13. If the parenthesis was omitted and aluminum hydroxide was written AlOH₃, how would that change the number of atoms of each element present in the compound?

**Exercising Your Knowledge**

14. How many of each element is present in aluminum hydroxide?
   a. Aluminum
   b. Oxygen
   c. Hydrogen
15. Complete the table below with the proper ions, chemical formulas, and compound names. The first row is completed as an example.

Table - 8

<table>
<thead>
<tr>
<th>Cation</th>
<th>Anion</th>
<th>Chemical Formula</th>
<th>Compound Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Na⁺</td>
<td>Cl⁻</td>
<td>NaCl</td>
<td>sodium chloride</td>
</tr>
<tr>
<td></td>
<td></td>
<td>LiCN</td>
<td>lithium cyanide</td>
</tr>
<tr>
<td>Ca⁺²</td>
<td>OH⁻</td>
<td></td>
<td>barium phosphate</td>
</tr>
<tr>
<td>Fe⁺²</td>
<td>NO₃⁻</td>
<td></td>
<td>barium phosphate</td>
</tr>
<tr>
<td>Cr⁺²</td>
<td>PO₃⁻³</td>
<td></td>
<td>barium phosphate</td>
</tr>
<tr>
<td>K⁺</td>
<td>SO₄⁻²</td>
<td></td>
<td>ammonium carbonate</td>
</tr>
<tr>
<td></td>
<td></td>
<td>AuPO₄</td>
<td>copper (II) hydroxide</td>
</tr>
</tbody>
</table>

Summarizing You Thoughts

16. Write a rule that can be used to determine whether or not parenthesis are needed when writing a chemical formula.

17. Make a list of information you must know in order to write the correct formula for an ionic compound (this list may require reviewing all of the activities so far).

18. Explain why the number of each ion is not included in the name of an ionic compound.
Chemical Bonding POGIL

Activity 8 – No metals...

Objective:
- Given a covalent compound’s name, be able to give the proper chemical formula for the compound.
- Given a covalent compound’s chemical formula, be able to give the proper name for the compound.

Getting Started:
We will be using gases and other compounds as illustrations of naming covalent compounds. Covalent compounds are defined as a groups of atoms that stay together because of shared electrons in chemical bonds. There are an infinite number of covalent compounds. Here, we will be focusing on naming some of the smaller covalent compounds.

The names of covalent compounds are similar to those of the ionic compounds, but there are differences. Use the Model to see if you can figure out how the rules differ.

The Model:
Table 9 – Covalent Compounds

<table>
<thead>
<tr>
<th>Compound Name</th>
<th>Compound Molecular Formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>phosphorus hexafluoride</td>
<td>PF₆</td>
</tr>
<tr>
<td>tetracarbon decahydride</td>
<td>C₄H₁₀</td>
</tr>
<tr>
<td>boron trichloride</td>
<td>BCl₃</td>
</tr>
<tr>
<td>dinitrogen monoxide</td>
<td>N₂O</td>
</tr>
<tr>
<td>carbon monoxide</td>
<td>CΟ</td>
</tr>
<tr>
<td>dinitrogen tetroxide</td>
<td>N₂O₄</td>
</tr>
</tbody>
</table>

Reviewing the Model

1. Where in the periodic table do you find all of the elements used in the Model (Table 9)?

2. What suffix is used for all of the compounds?

3. Is the name of the first element in each formula changed as it goes from an individual element to a compound?

4. How is the name of the second element in each name changed as it goes from an individual element to a compound?

5. How many atoms of nitrogen are present in dinitrogen tetroxide?

6. How many atoms of fluorine are present in phosphorus hexafluoride?
7. Use the Model to fill in the following table with prefixes used to designate the number of each type of atom in a binary compound.

<table>
<thead>
<tr>
<th>Prefix</th>
<th>Number of atoms of element</th>
</tr>
</thead>
<tbody>
<tr>
<td>(no prefix)</td>
<td>One</td>
</tr>
<tr>
<td></td>
<td>Two</td>
</tr>
<tr>
<td></td>
<td>Three</td>
</tr>
<tr>
<td></td>
<td>Four</td>
</tr>
<tr>
<td></td>
<td>Five</td>
</tr>
<tr>
<td></td>
<td>Six</td>
</tr>
<tr>
<td>Hepta-</td>
<td>Seven</td>
</tr>
<tr>
<td></td>
<td>Eight</td>
</tr>
<tr>
<td></td>
<td>Nine</td>
</tr>
<tr>
<td></td>
<td>Ten</td>
</tr>
</tbody>
</table>

**Exploring the Model**

8. Nitrogen oxide and nitrogen monoxide are both acceptable names for the compound with the chemical formula NO. What is the difference in these names, and why do you think the prefix is optional?

9. A dentist calls you up and needs to order more laughing gas for his dental clinic. You check in a chemistry reference and find that the chemical name for laughing gas is dinitrogen monoxide. You may order N₂O, NO or NO₂. One is the correct compound and the other two are toxic gases. Which should be ordered to keep the patients happy and alive?

**Exercising Your Knowledge**
From the information given above, complete the following table:
<table>
<thead>
<tr>
<th>Compound Name</th>
<th>Compound Molecular Formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>sulfur difluoride</td>
<td>PCl₃</td>
</tr>
<tr>
<td>silicon dioxide</td>
<td>H₂S</td>
</tr>
<tr>
<td>carbon tetrachloride</td>
<td>SiBr₂</td>
</tr>
<tr>
<td>carbon dioxide</td>
<td>P₄O₁₀</td>
</tr>
</tbody>
</table>

**Summarizing Your Thoughts**

10. In complete sentences state the rules for naming a covalent compound given the compound’s molecular formula.

11. Compare your rules for naming covalent compounds with the rules you established for writing the names of ionic compounds. Make sure your rules clearly help you decide when you use prefixes indicating the number of atoms and when you use Roman numerals.