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>
<thead>
<tr>
<th>Monatomic Ions</th>
<th>Nitride</th>
<th>Sulfide</th>
<th>Chloride</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>[N(^{3-})]</td>
<td>[S(^{2-})]</td>
<td>[Cl(^{-})]</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Polyatomic Ions</th>
<th>Nitrate</th>
<th>Sulfate</th>
<th>Ammonium</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>[O(_{4})N(^{3-})]</td>
<td>[S(<em>{4})O(</em>{6})(^{2-})]</td>
<td>[H(_{3})N(^{+})]</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Polyatomic Ions</th>
<th>Nitrite</th>
<th>Sulfite</th>
<th>Hydroxide</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>[O(_{3})N(^{1-})]</td>
<td>[S(<em>{3})O(</em>{5})(^{2-})]</td>
<td>[O(_{2})H(^{1-})]</td>
</tr>
</tbody>
</table>

1. Use model 1 to complete the table.

<table>
<thead>
<tr>
<th>Name of Ion</th>
<th>Nitride</th>
<th>Nitrate</th>
<th>Sulfate</th>
<th>Sulfite</th>
<th>Ammonium</th>
</tr>
</thead>
<tbody>
<tr>
<td>Charge on Ion</td>
<td>-1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Type and Number of Atoms</td>
<td></td>
<td>1 sulfur 4 oxygen</td>
<td></td>
<td>SO(_{3})(^{2-})</td>
<td></td>
</tr>
<tr>
<td>Chemical Formula</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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. 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.
6. How are ternary ionic compounds in Model 2 different from binary ionic compounds (NaCl, MgO, CaBr₂, etc.) that you’ve seen previously? Hint: Consider the meaning of the word “binary.”

7. Consider the compound iron(III) hydroxide in Model 2.
   a. How many hydroxide ions (OH⁻) are combined with an iron(III) ion (Fe³⁺)?
   b. Is your answer to part a the only combination of iron(III) and hydroxide that should exist in nature? Explain.

8. Consider the compound barium nitrite in Model 2.
   a. What does the subscripted “2” inside the parentheses of the chemical formula tell you about the compound? Ba(NO₂)₂
   b. What does the subscripted “2” outside the parentheses of the chemical formula tell you about the compound? Ba(NO₂)₂

9. How many atoms of each element are in one formula unit of ammonium phosphate, (NH₄)₃PO₄?
   - nitrogen
   - hydrogen
   - phosphorus
   - oxygen

10. 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.
       Calcium: Ca²⁺  Hydroxide: OH⁻
    b. Why is the student’s chemical formula for the compound calcium hydroxide wrong?

11. Write the chemical formulas for the following ternary ionic compounds.
    a. Calcium sulfate  b. Copper (II) nitrate  c. Lithium phosphate

12. Name the following ternary ionic compounds
    a. BaSO₄  b. NH₄NO₃  c. Fe(NO₃)₃

13. When asked to classify sodium acetate (NaCH₃COO) 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.

14. Are there any ionic compounds that contain no metals at all? Explain.

15. Make a list of the polyatomic ions and charges that you need to memorize.