INTRODUCTION

The formula of a compound describes the exact composition of a molecule of the compound. These formulas oftentimes were determined by tedious analysis of the compound itself.

A simpler method of determining the chemical formula of a compound is to use the concept of valence.

This method makes it much easier to predict the formulas for compounds even if we do not have a sample of the compound to physically work with.

OBJECTIVES

1. The student will define or identify the terms associated with valence as described in this unit.

2. The student will assign valence to atoms and radicals using the rules given in this unit and a Periodic Chart.

3. The student will use valence to write the correct formula for a compound.

DISCUSSION

A. Valence

The valence of an atom or group of atoms is a number that indicates the charge that an atom or group of atoms has when involved in a compound. The charge may be positive or negative and have values as low as a negative four (-4) to a positive seven (+7).

Atoms or groups of atoms with a positive valence are called cations.

Atoms or groups of atoms with a negative valence are called anions.

The valence of an atom is related to the number of valence electrons and thus to the position of an atom on the Periodic Chart.

The valence is written as a superscript to the atom. The number is preceded by a sign to indicate whether the valence is positive (+) or negative (-).

Following are some examples of atoms, or groups of atoms, and their valences.

<table>
<thead>
<tr>
<th>Atom or Compound</th>
<th>Valence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Na	extsuperscript{+1}</td>
<td>+1 (plus one)</td>
</tr>
<tr>
<td>Mg	extsuperscript{+2}</td>
<td>+2 (plus two)</td>
</tr>
<tr>
<td>N	extsuperscript{-3}</td>
<td>-3 (-minus three)</td>
</tr>
<tr>
<td>O	extsuperscript{-2}</td>
<td>-2 (minus two)</td>
</tr>
<tr>
<td>SO	extsubscript{4}	extsuperscript{-2}</td>
<td>-2 (minus two)</td>
</tr>
</tbody>
</table>

Note, that on the group of atoms SO	extsubscript{4}	extsuperscript{-2} the valence of minus two is associated with The entire group of atoms, not just the Oxygen, even though Oxygen has a minus two valence.
B. Rules of Valence

Many atoms have valences dependent on their position on the Periodic Chart. These atoms will always have a particular value of a valence in a compound.

Other atoms will have variable values for valence. These values will have to be determined by knowing the valence of the atom or atoms bound to them.

You must memorize the rules for assigning valence.

Rules for Valence

1. Atoms of group 1a have valences of plus one (+1) when they are in a compound. These elements are; Li, Na, K, Rb, Cs, and Fr.

2. Atoms of group 2a have valences of plus two (+2) when they are in a compound. These elements are; Be, Mg, Ca, Sr, Ba, and Ra.

3. Oxygen (O) has a valence of minus two (-2) in a compound when it is bound to a different element.

4. Fluorine (F) has a valence of minus one (-1) in a compound when it is bound to a different element.

5. Hydrogen (H) is always a plus one (+1) in a compound with a different element.

6. Radicals are groups of atoms that appear frequently in compounds. They have a valence associated with the particular radical. The name of the radical, its valence and its formula must be memorized.

Following is a list.

<table>
<thead>
<tr>
<th>Formula</th>
<th>Name</th>
<th>Valence</th>
</tr>
</thead>
<tbody>
<tr>
<td>SO$_{4}^{-2}$</td>
<td>Sulfate</td>
<td>-2</td>
</tr>
<tr>
<td>CO$_{3}^{-2}$</td>
<td>Carbonate</td>
<td>-2</td>
</tr>
<tr>
<td>NO$_{3}^{-1}$</td>
<td>Nitrate</td>
<td>-1</td>
</tr>
<tr>
<td>PO$_{4}^{-3}$</td>
<td>Phosphate</td>
<td>-3</td>
</tr>
<tr>
<td>NH$_{4}^{+1}$</td>
<td>Ammonium</td>
<td>+1</td>
</tr>
<tr>
<td>HCO$_{3}^{-1}$</td>
<td>Bicarbonate</td>
<td>-1</td>
</tr>
<tr>
<td>Cr$<em>{2}$O$</em>{7}^{-2}$</td>
<td>Dichromate</td>
<td>-2</td>
</tr>
<tr>
<td>MnO$_{4}^{-1}$</td>
<td>Permanganate</td>
<td>-1</td>
</tr>
<tr>
<td>C$<em>{2}$O$</em>{4}^{-2}$</td>
<td>Oxalate</td>
<td>-2</td>
</tr>
<tr>
<td>CrO$_{4}^{-2}$</td>
<td>Chromate</td>
<td>-2</td>
</tr>
<tr>
<td>SO$_{3}^{-2}$</td>
<td>Sulfite</td>
<td>-2</td>
</tr>
<tr>
<td>NO$_{2}^{-1}$</td>
<td>Nitrite</td>
<td>-1</td>
</tr>
</tbody>
</table>
7. The valence of the pure element is zero. This includes the diatomic compounds; H$_2$, O$_2$, F$_2$, Cl$_2$, Br$_2$, and I$_2$.

8. The sum of the valences in a compound equals zero or the charge on the compound.

These rules must be memorized. The valences for any atoms not mentioned will be given or can be determined by knowing the atoms they are bound to in a compound.

C. Chemical Formulas from Valence

The correct chemical formula for a compound can be determined by knowing the valence of the atom or radical and applying rule #8.

The procedure is as follows:

a. Determine the valence for the atoms or radicals involved.

b. Write the cation on the left and the anion on the right.

c. Include in the formula of the compound enough cations and anions so that the sum of the valences of each equals zero or the charge on the compound.

d. The number of each cation or anion is given by the subscript in the chemical formula.

e. If more than one radical is to be used, put the formula for the radical in parenthesis ( ) and then add the subscript.

Example Problem (1)

Write the formula of the compound Sodium Fluoride.

Solution

a. Determine valence.

Sodium (Na), a member of group 1a, is +1.

Fluorine (F) is always minus one (-1).

b. Write the cation on the left, anion on the right.

\[ \text{Na}^{+1} \quad \text{F}^{-1} \]

c. Write the formula by criss-crossing the valences and make them subscripts.

\[ \text{Na}_1 \quad \text{F}_1 \quad \text{or} \quad \text{NaF} \]

because ones are understood and not written as part of the formula.

The chemical formula for Sodium Fluoride is NaF.
Example Problem (2)

Write the formula for Magnesium Fluoride.

Solution

a. Valence Determination

\[ \text{Mg}^{+2}, \text{ group 2a} \]
\[ \text{F}^{-1}, \text{ always -1} \]

b. Cation then anion written out.

\[ \text{Mg}^{+2}, \text{ F}^{-1} \]

c. Valences, without signs cross-crossed and made subscripts.

\[ \text{MgF}_2 \]

The chemical formula for Magnesium Fluoride contains one Magnesium ion with a +2 valence, balanced by two Fluoride ions each with a -1 valence for a total of zero.

This can be represented as follows.

\[
\begin{array}{c|c}
\text{Mg}^{+2} & \text{F}^{-1} \\
\hline
\text{times the number of atoms equals} & \\
\text{total contribution to molecule} & +2 \quad -2 \\
\end{array}
\]

\[ +2 - 2 = 0 \]

Equals zero as required by rule 8.

Example Problem (3)

Write the formula of Calcium Phosphate.

Solution

a. Valence Determination

\[ \text{Ca}^{+2}, \text{ group 2a} \]
\[ \text{PO}_4^{-3}, \text{ always -3} \]

b. Cation and anion written out.

\[ \text{Ca}^{+2}, \text{ PO}_4^{-3} \]
c. Opposite valences become subscripts by criss-crossing them.

\[
\text{Ca}^{+2} \quad \text{PO}_{4}^{-3}
\]
\[
\text{Ca}_3 \quad (\text{PO}_{4})_2
\]

The radical Phosphate is put in parentheses to avoid confusion.

The formula for Calcium Phosphate contains three calcium cations each with a +2 charge for a total of +6, balanced by two phosphates each with a charge of –3 for a total of –6. The grand total equals zero.

This can be represented as follows.

\[
\begin{array}{c|c|c}
\text{Ca}^{+2} & \text{PO}_{4}^{-3} & \rightarrow \text{Valence per atom or radical} \\
\hline
\text{total contribution to compound} = +6 & -6 \\
\end{array}
\]

\[+6 - 6 = 0 \quad \text{Compound is neutral as required by rule 8.}\]

**Example Problem (4)**

Write the formula for Ammonium Oxalate.

**Solution**

a. \(\text{NH}_4^{+1}, \text{C}_2\text{O}_4^{-2}\)

b. \(\text{NH}_4^{+1} \quad \text{C}_2\text{O}_4^{-2}\)

c. \((\text{NH}_4)_2 \quad \text{C}_2\text{O}_4\)

This is the correct chemical formula for Ammonium Oxalate.
D. General Rules of Nomenclature

There are many rules governing the naming and writing of compounds and their formulas. Following are a few of the more general rules.

1. The cation is always named and written first, then the anion.
2. The names for the cations are the names of the elements.
3. The names of the radicals are unchanged.
4. Names of anions are changed as follows.
   - Oxygen to Oxide (O²⁻)
   - Fluorine to Fluoride (F⁻¹)
   - Chlorine to Chloride (Cl⁻¹)
   - Bromine to Bromide (Br⁻¹)
   - Iodine to Iodide (I⁻¹)
   - Sulfur to Sulfide (S⁻²)
   - Nitrogen to Nitride (N⁻³)

These can be used to construct and write the formulas for numerous compounds.
PROBLEMS

1. Define the terms.
   a. Valence
   b. Cation
   c. Anion
   d. Radical

2. Determine the valence on the following atoms and radicals
   a. Rb  b. Cs  c. Ba  d. O
   e. F  f. H  g. Nitrate  h. Nitrite
   i. Carbonate  j. Oxalate  k. Chromate  l. Dichromate

3. Write the formula for the following compounds.
   a. Potassium Fluoride
   b. Strontium Fluoride
   c. Sodium Oxide
   d. Barium Oxide
   e. Hydrogen Oxide (water)
   f. Ammonium Phosphate
   g. Barium Sulfate
   h. Sodium Nitrite
   i. Potassium Dichromate
   j. Potassium Permanganate
   k. Francium Bicarbonate
   l. Magnesium Carbonate
   m. Ammonium Fluoride