WRITING FORMULAS
EXPERIMENT 8

OBJECTIVE

The objective of this assignment is to write the formula of a compound given its elemental components.

DISCUSSION

Chemical formulas have two types of components: positive components (+ oxidation numbers) and negative components (- oxidation numbers).

In writing chemical formulas the positive components (cations) are always written before the negative components (anions).

In order to write the balanced chemical formula of a compound, the oxidation numbers of the component parts need to be known.

Using a periodic table, many of the oxidation numbers of the representative elements can be determined.

The elements in Group IA all have oxidation numbers of +1.
The elements in Group IIA all have oxidation numbers of +2.
The elements in Group IIIA all have oxidation numbers of +3.

The non-metals in Group V have oxidation numbers of either a positive +5 or a –3.
The non-metals in Group VI have oxidation numbers of either a positive +6 or a –2.
The non-metals in Group VII have oxidation numbers of either a positive +7 or a –1.

There are some transition elements that have fixed oxidation numbers (the number is always the same).

Zn = +2 Ag = +1

There are also many metals that have more than one oxidation number (variable oxidation numbers). Some of the most common are:

Fe = +2 or +3 Cu and Hg = +1 or +2 Pb and Sn = +2 or +4

There are two ways to determine which oxidation number to use for a variable oxidation metals: either be told what it is or calculate the oxidation number. In a later experiment on naming compounds, you will be taught how to calculate the oxidation number from the formula or the name. In this experiment, you will be given the number.

The nonmetals can either have a positive or negative oxidation depending on whether they are donating electrons (+ oxidation number) or accepting electrons (- oxidation number). Metals always have positive oxidation numbers.

The easiest way to understand the oxidation numbers is to consider that elements with negative oxidation numbers need that many electrons and elements with positive oxidation numbers have that many electrons to give away.

The Law of Conservation of Mass states that mass can neither be created nor destroyed by normal chemical means. Electrons have mass, therefore, if one element gives away an electron, another has to accept it. Since metals always give away electrons and will not take an electron, metals alone can never form compounds. There always has to be a non-metal if there is a metal in the compound. On the other hand, since non-metals can accept or give electrons, compounds can consist of only non-metals.

In a chemical formula, the positive oxidation component (cation) is written first followed by the negative component (anion).

For a chemical formula to be balanced, the total number of electrons being given away must equal the number of electron being accepted. This means that the sum of the positive oxidation numbers must equal the sum of the negative oxidation numbers. The total sum of all the oxidation numbers must equal zero.

In a chemical formula the number of atoms of each element must always be in whole number ratios. There cannot be a fractional part of an atom.

Binary Compounds

We will first start with compounds that only have two elements (binary). One element must be have a positive oxidation number and the other a negative oxidation number.

The ion with the positive oxidation number will be written first, followed by the negative ion. Remember that metals always have positive oxidation numbers, so will always come first followed by a non-metal.

Example: sodium and chlorine

sodium is in Group IA therefore has a +1 oxidation number
chlorine is in Group VII A therefore has either a +7 or a –1 oxidation number.

Since there is already a metal, the chloride in this case must be the negative oxidation number –1.

This gives the following oxidation numbers: Na^{+1} and Cl^{-1}

Na^{+1} means that sodium has one electron to donate.
Cl^{-1} means that chlorine can accept one electron.

If the positive and negative oxidation numbers are added (+1-1), the sum is zero.

Therefore, the chemical formula would be NaCl.

Example: sodium and oxygen

sodium is in Group IA therefore has a +1 oxidation number
oxygen is in Group VI A therefore has either a +6 or a –2 oxidation number.

Since there is already a metal, the oxygen in this case must be the negative oxidation number –2.

This gives the following oxidation numbers: Na^{+1} and O^{-2}

Na^{+1} means that sodium has one electron to donate.
O^{-2} means that oxygen can accept two electrons.

If the positive and negative oxidation numbers are added (+1-2), the sum is not zero. This is because an individual Na atom can only donate one electron but an oxygen atom needs two electrons. In order to satisfy the oxygen, two sodium atoms must be used.

Na^{+1} + Na^{+1} + O^{-2} = zero (+1+1-2)

The formulas therefore would be written as Na_2O.

Example: aluminum and oxygen

aluminum is in Group IIIA therefore has a +3 oxidation number
oxygen is in Group VI A therefore has either a +6 or a –2 oxidation number.

Since there is already a metal, the oxygen in this case must be the negative oxidation number –2.

This gives the following oxidation numbers: Al^{+3} and O^{-2}

Al^{+3} means that sodium has three electrons to donate.
O^{-2} means that oxygen can accept two electrons.

If the positive and negative oxidation numbers are added (+3-2), the sum is not zero.

This is because an individual Al atom needs donate three electrons but an oxygen atom needs only two electrons. Remember that we cannot have a part of an atom.

In order to balance the electrons donated and accepted, multiple the two oxidation numbers together (2 x 3 = 6). The number of aluminum atoms needed would be 6/+3=2. The number of oxygen atoms needed would be 6/-2=3..

Al^{+3} Al^{+3} + O^{-2} + O^{-2} + O^{-2} = zero (+3+3-2-2-2)

The formulas therefore would be written as Al_2O_3.

Ternary Compounds

Ternary compounds have more than two elements. The ternary compounds we will use in this discussion will consist of a metal and a polyatomic ion. The metal must be have a positive oxidation number and the polyatomic a negative oxidation number.

The ion with the positive oxidation number will be written first, followed by the negative polyatomic ion. Remember that metals always have positive oxidation numbers, so they will always come first followed by the polyatomic.

The following is a list of common polyatomic ions.

Common Polyatomic Ions					
Sulfate	SO_4^{-2}	nitrate	NO_3^{-1}	acetate	$C_2H_3O_2^{-1}$
Phosphate	PO_4^{-3}	hydroxide	OH^{-1}	bicarbonate	HCO_3^{-1}
Carbonate	CO_3^{-2}	cyanide	CN^{-1}	chlorate	ClO_3^{-1}

Treat the polyatomic ions as units. The oxidation number is for the entire polyatomic ion.

Example: sodium and carbonate

sodium is in Group IA therefore has a +1 oxidation number.
carbonate has a -2 oxidation number.

This gives the following oxidation numbers: Na^{+1} and CO_3^{-2}

Na^{+1} means that sodium has one electron to donate.
CO_3^{-2} means that chlorine can accept two electrons.

If the positive and negative oxidation numbers are added (+1-2), the sum is not zero. This is because an individual Na atom can only donate one electron but a carbonate ion needs two electrons. In order to satisfy the carbonate, two sodium atoms must be used.

Na^{+1} + Na^{+1} + CO_3^{-2} = zero (+1+1-2) or (+1 x 2 = +2 and +2 – 2 = 0)

The formulas therefore would be written as Na_2CO_3

When there is more than one polyatomic ion, the polyatomic ion is enclosed in parenthesis with a subscript following to indicate how many polyatomic ions there are. Never use parenthesis when there is only one polyatomic ion in the formula.

Examples of molecules with more than one polyatomic:

$Al\,(OH)_3$ $Mg(NO_3)_2$ $Ba_3(PO_4)_2$ $Ca(CN)_2$ $Mg(C_2H_3O_2)_2$

Example: calcium and hydroxide

calcium is in Group IIA therefore has a +2 oxidation number.
hydroxide has a -1 oxidation number.

This gives the following oxidation numbers: Ca^{+2} and OH^{-1}

Ca^{+2} means that calcium has two electrons to donate.
OH^{-1} means that the hydroxide can accept one electron.

If the positive and negative oxidation numbers are added (+2-1), the sum is not zero. This is because an individual Ca atom can donate two electrons but a hydroxide ion can only accept one electron. In order to satisfy the calcium, two hydroxide ions must be used.

$Ca^{+2} + OH^{-1} + OH^{-1}$ = zero (+2-1-1) or (-1 x 2 = -2 and +2 – 2 = 0)

Notice that there are more than one hydroxide ions needed. Since there is more that one hydroxide ion, the hydroxide ion would be place between parentheses followed by the number 2.

$(OH)_2$ This means two OH. In other words: OH^{-1} and OH^{-1} .

If it were written as OH_2 without the parentheses, this would indicate only one oxygen atom and two hydrogen atoms. What are really needed are two of each.

The formulas therefore would be written as $Ca(OH)_2$

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SECTION _________________

WRITING FORMULAS
REPORT SHEET
EXPERIMENT 8

BINARY COMPOUNDS

Complete the following table by writing the balanced formulas:

Cations	Anions							
	F^{-1}	Cl^{-1}	Br^{-1}	I^{-1}	O^{-2}	S^{-2}	N^{-3}	P^{-3}
H^{+1}								
Li^{+1}								
Na^{+1}								
K^{+1}								
Cs^{+1}								
Be^{+2}								
Mg^{+2}								
Ca^{+2}								
Sr^{+2}								
Ba^{+2}								
Al^{+3}								
Fe^{+2}								
Fe^{+3}								
Pb^{+4}								
Cu^{+1}								
Zn^{+2}								
Ag^{+1}								

Write the formulas for the following cations and anions:

Cation	Anion	Formula
calcium	chlorine	
sodium	oxygen	
potassium	nitrogen	
hydrogen	sulfur	
magnesium	bromine	
aluminum	iodine	
barium	oxygen	
calcium	sulfur	
sodium	phosphorus	
magnesium	nitrogen	
aluminum	oxygen	
iron +2	chlorine	
iron +3	bromine	
lead +2	iodine	
lead +4	nitrogen	
tin +2	phosphorus	
tin +4	oxygen	
copper +1	sulfur	
copper +2	chlorine	
strontium	iodine	
cesium	oxygen	
zinc	nitrogen	
silver	sulfur	
hydrogen	chlorine	
hydrogen	oxygen	

TERNARY COMPOUNDS

Complete the following table by writing the balanced formulas:

Cations	Polyatomic anions			
	SO_4^{-2}	NO_3^{-1}	CO_3^{-2}	OH^{-1}
H^{+1}				
Li^{+1}				
Na^{+1}				
K^{+1}				
Cs^{+1}				
Be^{+2}				
Mg^{+2}				
Ca^{+2}				
Sr^{+2}				
Ba^{+2}				
Al^{+3}				
Fe^{+2}				
Fe^{+3}				
Pb^{+4}				
Cu^{+1}				
Zn^{+2}				
Ag^{+1}				

Complete the following table by writing the balanced formulas:

Cations	Polyatomic anions			
	PO_4^{-3}	ClO_3^{-1}	CN^{-1}	HCO_3^{-1}
H^{+1}				
Li^{+1}				
Na^{+1}				
K^{+1}				
Cs^{+1}				
Be^{+2}				
Mg^{+2}				
Ca^{+2}				
Sr^{+2}				
Ba^{+2}				
Al^{+3}				
Fe^{+2}				
Fe^{+3}				
Pb^{+4}				
Cu^{+1}				
Zn^{+2}				
Ag^{+1}				

Write the formulas for the following cations and anions:

Cation	Polyatomic ion	Formula
hydrogen	carbonate	
hydrogen	hydroxide	
hydrogen	sulfate	
hydrogen	phosphate	
hydrogen	nitrate	
hydrogen	acetate	
hydrogen	cyanide	
hydrogen	bicarbonate	[redacted]
magnesium	carbonate	
magnesium	hydroxide	
magnesium	sulfate	
magnesium	phosphate	
magnesium	nitrate	
magnesium	acetate	
magnesium	cyanide	
magnesium	bicarbonate	
potassium	carbonate	
potassium	hydroxide	
potassium	sulfate	
potassium	phosphate	

potassium	nitrate	
potassium	acetate	
potassium	cyanide	
potassium	bicarbonate	
aluminum	carbonate	
aluminum	hydroxide	
aluminum	sulfate	
aluminum	phosphate	
aluminum	nitrate	
aluminum	acetate	
aluminum	cyanide	
aluminum	bicarbonate	
iron +3	carbonate	
iron +3	hydroxide	
iron +3	sulfate	
iron +3	phosphate	
iron +3	nitrate	
iron +3	acetate	
iron +3	cyanide	
iron +3	bicarbonate	
zinc	carbonate	
zinc	hydroxide	

zinc	sulfate	
zinc	phosphate	
zinc	nitrate	
zinc	acetate	
zinc	cyanide	
zinc	bicarbonate	
lead +4	carbonate	
lead +4	hydroxide	
lead +4	sulfate	
lead +4	phosphate	
lead +4	nitrate	
lead +4	acetate	
lead +4	cyanide	
lead +4	bicarbonate	
lead +4	carbonate	
copper +1	sulfate	
iron +2	phosphate	
silver	carbonate	