Tutorial 2

FORMULAS, PERCENTAGE COMPOSITION, AND THE MOLE

FORMULAS: A chemical formula shows the elemental composition of a substance: the chemical symbols show what elements are present and the numerical subscripts show how many atoms of each element there are in a formula unit. Examples:

$NaCl$: one sodium atom, one chlorine atom in a formula unit
$CaCl_2$: one calcium atom, two chlorine atoms in a formula unit
Mg_3N_2: three magnesium atoms, two nitrogen atoms in a formula unit

The presence of a metal in a chemical formula indicates an ionic compound, which is composed of positive ions (cations) and negative ions (anions). A formula with only nonmetals indicates a molecular compound (unless it is an ammonium, NH_4^+, compound). Only ionic compounds are considered in this Tutorial.

There are tables of common ions in your lecture text, p 56 (cations) and p 57 (anions). A combined table of these same ions can be found on the inside back cover of the lecture text. A similar list is on the next page; all formulas needed in this and subsequent Tutorial problems can be written with ions from this list.

Writing formulas for ionic compounds is very straightforward: TOTAL POSITIVE CHARGES MUST BE THE SAME AS TOTAL NEGATIVE CHARGES. The formula must be neutral. The positive ion is written first in the formula and the name of the compound is the two ion names.

EXAMPLE: Write the formula for potassium chloride.

The name tells you there are potassium, K^+, and chloride, Cl^-, ions. Each potassium ion is +1 and each chloride ion is -1: one of each is needed, and the formula for potassium chloride is KCl. "1" is never written as a subscript.

EXAMPLE: Write the formula for magnesium hydroxide.

This contains magnesium, Mg^{2+}, and hydroxide, OH^-, ions. Each magnesium ion is +2 and each hydroxide ion is -1: two -1 ions are needed for one +2 ion, and the formula for magnesium hydroxide is $Mg(OH)_2$. The $(OH)_2$ indicates there are two OH^- ions. In a formula unit of $Mg(OH)_2$, there are one magnesium ion and two hydroxide ions; or one magnesium, two oxygen, and two hydrogen atoms. The subscript multiplies everything in ( ).

EXAMPLE: Write the formula for aluminum sulfate.

This contains aluminum, Al^{3+}, and sulfate, SO_4^{2-}, ions. The lowest common multiple of 3 and 2 is 6, so we will need six positive and six negative charges: two Al^{3+} and three SO_4^{2-} ions, and the formula for aluminum sulfate is $Al_2(SO_4)_3$. Then, in a formula unit of $Al_2(SO_4)_3$ there are two aluminum ions and three sulfate ions; or two aluminum, three sulfur, and twelve oxygen atoms.

COMMON POSITIVE IONS

H^+	hydrogen
NH_4^+	ammonium
Li^+	lithium
Na^+	sodium
K^+	potassium
Mg^{2+}	magnesium
Ca^{2+}	calcium
Sr^{2+}	strontium
Ba^{2+}	barium
Al^{3+}	aluminum
Sn^{2+}	tin(II)
Sn^{4+}	tin(IV)
Pb^{2+}	lead(II)[1]
Bi^{3+}	bismuth
Cr^{3+}	chromium(III)[2]
Mn^{2+}	manganese(II)[3]
Fe^{2+}	iron(II)
Fe^{3+}	iron(III)
Co^{2+}	cobalt(II)[4]
Ni^{2+}	nickel(II)[5]
Cu^+	copper(I)
Cu^{2+}	copper(II)
Ag^+	silver
Zn^{2+}	zinc
Cd^{2+}	cadmium
Hg_2^{2+}	mercury(I)
Hg_2^{2+}	mercury(II)

COMMON NEGATIVE IONS

$[Fe(CN)_6]^{3-}$	ferricyanide
$[Fe(CN)_6]^{4-}$	ferrocyanide
PO_4^{3-}	phosphate
HPO_4^{2-}	hydrogen phosphate
$H_2PO_4^-$	dihydrogen phosphate
CO_3^{2-}	carbonate
HCO_3^-	hydrogen carbonate
SO_3^{2-}	sulfite
HSO_3^-	hydrogen sulfite
SO_4^{2-}	sulfate
HSO_4^-	hydrogen sulfate
$S_2O_3^{2-}$	thiosulfate
CrO_4^{2-}	chromate
$Cr_2O_7^{2-}$	dichromate
O^{2-}	oxide
O_2^{2-}	peroxide
S^{2-}	sulfide
HS^-	hydrogen sulfide

COMMON NEGATIVE IONS

$C_2H_3O_2^-$	acetate
CN^-	cyanide
CNO^-	cyanate
SCN^-	thiocyanate
ClO^-	hypochlorite
ClO_3^-	chlorate
ClO_4^-	perchlorate
IO_3^-	iodate
MnO_4^-	permanganate
NO_2^-	nitrite
NO_3^-	nitrate
OH^-	hydroxide
IO_4^-	periodate
H^-	hydride
F^-	fluoride
Cl^-	chloride
Br^-	bromide
I^-	iodide

[1]There is also a lead(IV)
[2]There is also a chromium(II)
[3]There is also a manganese(III)
[4]There is also a cobalt(III)
[5]There is also a nickel(III)

PERCENTAGE COMPOSITION: Imagine a class of 40 boys and 60 girls: 100 students total. 40/100 of the students are boys and 60/100 girls; or, 40% boys and 60% girls. The "%" sign means percent, or parts per 100.

Suppose a class has 10 boys and 15 girls, for a total of 25 students. If you want to find out how many boys there would be per 100 students, keeping the same ratio of boys to girls, the following proportion can be set up:

$$\frac{10 \text{ boys}}{25 \text{ students}} = \frac{\text{X boys}}{100 \text{ students}}$$

This means: "if there are 10 boys per 25 students, then there would be X boys per 100 students." Solving this equation,

$$X = \frac{10 \text{ boys}}{25 \cancel{\text{ students}}} \times 100 \cancel{\text{ students}} = 40 \text{ boys}$$

There would be 40 boys per 100 students, or 40% boys. Percent calculation is based on this kind of proportion. However, you do not have to set up the proportion each time you want to find percent composition. Simply divide the number of parts you are interested in (number of boys) by the total number of parts (number of students), and multiply by 100. This is exactly what we did to find X in the above example.

DIVIDE THE PART BY THE WHOLE AND MULTIPLY BY 100

Suppose a mixture contains 12.4 g salt, 15.3 g sugar and 50.3 g sand, for a total 78.0 g of mixture. The percentage of each component in the mixture can be found by dividing the amount of each (PART) by the total amount (WHOLE) and multiplying by 100:

$$\frac{12.4 \text{ g}}{78.0 \text{ g}} \times 100 = 15.9\% \text{ salt} \qquad \frac{15.3 \text{ g}}{78.0 \text{ g}} \times 100 = 19.6\% \text{ sugar}$$

$$\frac{50.3 \text{ g}}{78.0 \text{ g}} \times 100 = 64.5\%$$

The sum of these percentages is 100%. Everything must total 100%.

Percentage is written without units but the units are understood to be "parts of whatever per 100 total parts." The "parts" and "whole" may be in any units as long as they are both in the same units. In the case of the above mixture, units could be put on the numbers and the percentages then used as conversion factors. For example, the 15.9% salt could become

$$\frac{15.9 \text{ g salt}}{100.0 \text{ g mixture}} \quad \text{or} \quad \frac{100.0 \text{ pounds mixture}}{15.9 \text{ pounds salt}} \quad \text{or} \quad \frac{15.9 \text{ tons salt}}{100.0 \text{ tons mixture}}$$

Et cetera. We do not usually care about composition of salt/sugar/sand mixtures, but we do care about percentage composition of pure chemical substances. Unless otherwise stated we always mean percent by mass (weight).

The formula mass of a substance is the sum of the atomic masses of all the atoms in the formula. For example, the formula mass of sodium chloride, NaCl, 58.44, is the sum of the atomic mass of sodium, 22.99, and the atomic mass of chlorine, 35.45. The formula mass of sodium sulfate, Na_2SO_4, is found as follows:

2 Na:	2 x 22.99	= 45.98	→	45.98 g Na	or	45.98 lbs Na
1 S:	1 x 32.06	= 32.06	→	32.06 g S	or	32.06 lbs S
4 O:	4 x 16.00	= 64.00	→	64.00 g O	or	64.00 lbs O
Formula mass		= 142.04		142.04 g Na_2SO_4		142.04 lbs Na_2SO_4

Atomic mass and formula mass are in atomic mass units, but are usually written without units. However, since these are relative masses of the atoms any mass unit can be used, as shown by the two columns to the right of the arrows, above.

In terms of atomic masses: in a total of 142.02 parts by mass of sodium sulfate, 45.98 parts are sodium, 32.06 parts are sulfur, and 64.00 parts are oxygen.

In terms of a gram mass unit (molar mass): in a total of 142.04 g of sodium sulfate, 45.98 g are sodium, 32.06 g are sulfur, and 64.00 g are oxygen.

In terms of pound mass unit: in a total of 142.06 lbs of sodium sulfate, 45.98 lbs are sodium, 32.06 lbs are sulfur, and 64.00 lbs are oxygen.

Percent composition can be determined with the mass ratios from the formula mass:

Sodium: $\dfrac{45.98}{142.04}$ x 100 = 32.37% Na → 32.37 g Na or 32.37 lbs Na

Sulfur: $\dfrac{32.06}{142.04}$ x 100 = 22.57% S → 22.57 g S or 22.57 lbs S

Oxygen: $\dfrac{64.00}{142.04}$ x 100 = 45.06% O → 45.06 g O or 45.06 lbs O

Total = 100.00%   100.00 g total   100.00 lbs total

As mentioned before, percentage is written without any units but the units are understood to be "parts of whatever per 100 total parts". Since these are relative masses any mass unit can be used, as shown by the two columns to the right of the arrows, above.

In terms of percentage: in a total of 100.00 parts by mass of sodium sulfate, 32.37 parts are sodium, 22.57 parts are sulfur, and 45.06 parts are oxygen.

In terms of a gram mass unit (molar mass): in a total of 100.00 g of sodium sulfate, 32.36 g are sodium, 22.57 g are sulfur, and 45.06 g are oxygen.

In terms of a pound mass unit: in a total of 100.00 lbs of sodium sulfate, 32.36 lbs are sodium, 22.57 lbs are sulfur, and 45.06 lbs are oxygen.

In the preceding calculations, the percent of each element in the substance was found. The percent of groups of elements may also be calculated. Suppose you want percent sulfate, SO_4^{2-}, in sodium sulfate. The formula mass of sodium sulfate is 142.04 and of that total 32.06 + 64.00 = 96.06 is sulfate. Thus,

Sulfate: $\dfrac{96.06}{142.04}$ x 100 = 67.63% SO_4^{2-}

Notice: this is the sum of the percents sulfur and oxygen: 22.57% S + 45.06% 0 = 67.63% SO_4^{2-}.

We may say sodium sulfate is 32.37% sodium, 22.57% sulfur, and 45.06% oxygen; or, 32.37% sodium and 67.63% sulfate. The total is 100% in either case.

We now have two sets of numbers which show mass relationships among the elements in sodium sulfate: (1) the formula mass and (2) the percentage composition.

From the formula mass on page T-9 various mass ratios, that is, conversion factors, may be obtained:

$$\frac{45.98 \text{ g Na}}{142.04 \text{ g } Na_2SO_4} \quad \text{or} \quad \frac{142.04 \text{ lbs } Na_2SO_4}{32.06 \text{ lbs S}} \quad \text{or} \quad \frac{32.06 \text{ g S}}{45.98 \text{ g Na}} \quad \text{and others}$$

From the percentages on page T-10 various mass ratios may also be obtained:

$$\frac{32.37 \text{ g Na}}{100.00 \text{ g } Na_2SO_4} \quad \text{or} \quad \frac{100.00 \text{ lbs } Na_2SO_4}{22.57 \text{ lbs S}} \quad \text{or} \quad \frac{22.57 \text{ g S}}{32.37 \text{ g Na}} \quad \text{and others}$$

We can now solve problems like the following:

<u>EXAMPLE</u>: What mass of sulfur is contained in 17.2 g of sodium sulfate?

Use formula mass ratios on page T-9 for the appropriate conversion factor:

$$17.2 \text{ g } Na_2SO_4 \times \frac{32.06 \text{ g S}}{142.04 \text{ g } Na_2SO_4} = 3.88 \text{ g S}$$

<u>OR</u>, use percentage composition ratios on page T-10:

$$17.2 \text{ g } Na_2SO_4 \times \frac{22.57 \text{ g S}}{100.00 \text{ g } Na_2SO_4} = 3.88 \text{ g S}$$

EXAMPLE: What mass of sodium is combined with 10.0 g of sulfur in sodium sulfate?

You may use a conversion factor from the formula masses OR percentage composition:

$$10.0\ \cancel{g\ S} \times \frac{45.98\ g\ Na}{32.06\ \cancel{g\ S}} = 14.3\ g\ Na$$

OR

$$10.0\ \cancel{g\ S} \times \frac{32.37\ g\ Na}{22.57\ \cancel{g\ S}} = 14.3\ g\ Na$$

Obviously, you do not have to calculate percent composition every time you do a problem like this: use formula mass ratios; if the percentage composition is given, then use it.

THE MOLE: The most important concept you encounter this semester in Chemistry is the mole. The mole may be defined:

> The mole is the amount (mass) of a substance which contains the same number of units (atoms, molecules, ions) as there are atoms in exactly 12 mass units of the carbon-12, ^{12}C, isotope.

It does not matter what mass units are used as long as the same mass units are used for the substance and the carbon-12. This is a strict definition of the mole, but it is operationally useless. A mole of a monoatomic element is the atomic mass taken with mass units; a mole of anything else is the formula mass taken with mass units. The kind of mole you get depends on the mass units you use. For example:

> 22.99 grams Na = 1 gram-mole Na has the same number of Na atoms as the number of atoms in 12 grams of ^{12}C.
>
> 63.55 milligrams Cu = 1 milligram-mole Cu has the same number of Cu atoms as the number of atoms in 12 milligrams of ^{12}C.
>
> 70.90 grams Cl_2 = 1 gram-mole Cl_2 has the same number of Cl_2 molecules as the number of atoms in 12 grams of ^{12}C.
>
> 253.80 lbs I_2 = 1 lb-mole I_2 has the same number of I_2 molecules as the number of atoms in 12 lbs of ^{12}C.
>
> 58.44 grams NaCl = 1 gram-mole NaCl has the same number of NaCl formula units as the number of atoms in 12 grams of ^{12}C.

142.04 tons Na_2SO_4 = 1 ton-mole Na_2SO_4 has the same number of Na_2SO_4 formula units as the number of atoms in 12 tons of ^{12}C.

18.02 g H_2O = 1 gram-mole H_2O has the same number of H_2O molecules as the number of atoms in 12 g of ^{12}C.

137.32 kg PCl_3 = 1 kilogram-mole PCl_3 has the same number of PCl_3 molecules as the number of atoms in 12 kg of ^{12}C.

Chemists generally use the gram-mole, written mole, abbreviated mol. This is the mole your textbook uses and is the only one for which Avogadro's Number is applicable. In one gram-mole of a substance there is Avogadro's Number of units: 6.022×10^{23} of them. Unless further qualification is noted the term "mole" is understood to mean the gram-mole.

Each of the equalities above becomes a conversion factor:

$$22.99 \text{ g Na} = 1 \text{ mol Na} \quad \text{becomes} \quad \frac{22.99 \text{ g Na}}{1 \text{ mol Na}} \quad \text{or} \quad \frac{1 \text{ mol Na}}{22.99 \text{ g Na}}$$

And so on.

<u>EXAMPLE</u>: How many moles is 31.65 g of sodium metal?

$$31.65 \cancel{\text{ g Na}} \times \frac{1 \text{ mol Na}}{22.99 \cancel{\text{ g Na}}} = 1.377 \text{ mol Na}$$

<u>EXAMPLE</u>: What is the mass of 0.362 mol of sodium sulfate?

$$0.362 \cancel{\text{ mol } Na_2SO_4} \times \frac{142 \text{ g } Na_2SO_4}{1 \cancel{\text{ mol } Na_2SO_4}} = 51.4 \text{ g } Na_2SO_4$$

The number of significant figures used in the atomic mass or formula mass should be at least as many as in the given (measured) data.

<u>EXAMPLE</u>: How many atoms of copper are in a 125 mg sample of copper metal?

When a problem asks "how many atoms or molecules" or "what is the mass of an atom or molecule," you must use Avogadro's Number. The units associated with that Number then depend on the problem. In this problem you are looking for atoms of copper so the units will be:

$$\frac{6.022 \times 10^{23} \text{ atoms Cu}}{1 \text{ mol Cu}}$$

The number of atoms of copper is related to moles of copper; moles of copper is related to grams of copper; the mass of copper given in the problem is in milligrams. The conversion sequence will be:

$$\text{mg Cu} \rightarrow \text{g Cu} \rightarrow \text{mol Cu} \rightarrow \text{atoms Cu}$$

$$125 \cancel{\text{ mg Cu}} \times \frac{1 \cancel{\text{ g Cu}}}{1000 \cancel{\text{ mg Cu}}} \times \frac{1 \cancel{\text{ mol Cu}}}{63.5 \cancel{\text{ g Cu}}} \times \frac{6.022 \times 10^{23} \text{ atoms Cu}}{1 \cancel{\text{ mol Cu}}} =$$

$$1.19 \times 10^{21} \text{ atoms Cu}$$

<u>EXAMPLE</u>: What is the mass of one water molecule?

This time the units associated with Avogadro's Number are

$$\frac{6.022 \times 10^{23} \text{ } H_2O \text{ molecules}}{1 \text{ mol } H_2O}$$

We are converting from a number of molecules (1, an exact number) to mass:

$$1 \cancel{H_2O \text{ molecule}} \times \frac{\cancel{1 \text{ mol } H_2O}}{6.022 \times 10^{23} \cancel{H_2O \text{ molecules}}} \times \frac{18.0 \text{ g } H_2O}{\cancel{1 \text{ mol } H_2O}} =$$

$$2.99 \times 10^{-23} \text{ g } H_2O$$

If four significant figures had been used for the formula mass of water, 18.02, the answer would have been 2.992×10^{-23} g H_2O. In this case the precision of the answer depends on the conversion factors, since the given data is an exact number.

Chemical formulas should be considered in terms of moles of atoms combined: the formula NaCl means there is one mole of sodium combined with one mole of chlorine; the formula H_2O means there are two moles of hydrogen combined with one mole of oxygen to form one mole of water.

The formula mass for sodium sulfate was calculated on page T-9. Referring to those numbers, the formula Na_2SO_4 means: two moles sodium (45.98 g), one mole sulfur (32.06 g), and four moles oxygen (64.00 g) combine to form one mole of sodium sulfate (142.04 g). Let us use this concept and do the first problem on page T-11 a different way:

EXAMPLE: What mass of sulfur is contained in 17.2 g of sodium sulfate?

$$17.2\ \cancel{\text{g } Na_2SO_4} \times \frac{\cancel{1 \text{ mol } Na_2SO_4}}{142\ \cancel{\text{g } Na_2SO_4}} \times \frac{\cancel{1 \text{ mol S}}}{\cancel{1 \text{ mol } Na_2SO_4}} \times \frac{32.1 \text{ g S}}{\cancel{1 \text{ mol S}}} = 3.89 \text{ g S}$$

Please notice: The same numbers are used in the same places, so the overall arithmetic is the same. The thought process is different: on page T-11 we thought in terms of mass ratios, now we are thinking in terms of mole ratios.

This answer is slightly different from the one obtained on page T-11. Can you see why?

EMPIRICAL (SIMPLEST) FORMULA: The empirical formula is the formula expressed as the lowest whole number ratio of atoms; it may or may not be the same as the formula. The empirical formula and formula of water, H_2O, are the same; the empirical formula of phosphorous pentoxide is P_2O_5, but the formula is P_4O_{10}. The empirical formula is derived solely from experimental, percentage composition data. On page T-10 we calculated percentage composition from a formula; let us now calculate an empirical formula from percentage composition data. Fundamental to this calculation is the fact: chemical formulas show mole ratios of elements.

EXAMPLE: Calculate the empirical formula for a compound with the analysis:

32.37% Na　　22.57% S　　45.06% O

Remember percentage means "parts of whatever per 100 total parts," so let us translate these percentages into grams of each element out of a total 100 grams of compound. Then convert these masses to moles:

$$32.37\ \cancel{\text{g Na}} \times \frac{1 \text{ mol Na}}{22.99\ \cancel{\text{g Na}}} = 1.408 \text{ mol Na}$$

$$22.57\ \cancel{\text{g S}} \times \frac{1 \text{ mol S}}{32.06\ \cancel{\text{g S}}} = 0.7040 \text{ mol S}$$

$$45.06\ \cancel{\text{g O}} \times \frac{1 \text{ mol O}}{16.00\ \cancel{\text{g O}}} = 2.816 \text{ mol O}$$

Please note: these are the number of moles of each element contained in 100.00 g of compound.

Now find the ratio of moles of each element to the smallest number of moles, by dividing each number of moles by the smallest:

$$\frac{1.408 \text{ mol Na}}{0.7040 \text{ mol S}} = 2.000 \text{ mol Na / mol S}$$

$$\frac{0.7040 \text{ mol S}}{0.7040 \text{ mol S}} = 1.000$$

$$\frac{2.816 \text{ mol O}}{0.7040 \text{ mol S}} = 4.000 \text{ mol O / mol S}$$

These ratios say there are 2 mol Na per 1 mol S; and 4 mol O per 1 mol S. The lowest whole-number ratio of moles is: $Na_2S_1O_4$; and since we do not write "1" as a subscript, the formula is: Na_2SO_4.

Sometimes these two steps do not give whole number ratios. In that case an additional step is needed, as shown below.

<u>EXAMPLE</u>: Calculate the empirical formula for a compound with the analysis:

29.1% Na 40.5% S 30.4% O

Let us do as with the previous EXAMPLE: (1) translate the percents into grams of the element per 100 g of compound and find moles of each element; then (2) find the ratio of moles of each element to the smallest number of moles:

$$29.1 \cancel{\text{ g Na}} \times \frac{1 \text{ mol Na}}{23.0 \cancel{\text{ g Na}}} = 1.27 \text{ mol Na} \qquad \frac{1.27 \text{ mol Na}}{1.26 \text{ mol S}} = 1.01 \text{ mol Na/mol S}$$

$$40.5 \cancel{\text{ g S}} \times \frac{1 \text{ mol S}}{32.1 \cancel{\text{ g S}}} = 1.26 \text{ mol S} \qquad \frac{1.26 \text{ mol S}}{1.26 \text{ mol S}} = 1.00$$

$$30.4 \cancel{\text{ g O}} \times \frac{1 \text{ mol O}}{16.0 \cancel{\text{ g O}}} = 1.90 \text{ mol O} \qquad \frac{1.90 \text{ mol O}}{1.26 \text{ mol S}} = 1.51 \text{ mol O/mol S}$$

These ratios say there is 1 mol Na per 1 mol S, and 1.5 mol O per 1 mol S, which are not whole number ratios. To make them whole number ratios we must multiply each by 2, giving ratios of 2 mol Na per 2 mol S and 3 mol O per 2 mol S; and the formula is $Na_2S_2O_3$.

Thus, in cases where steps (1) and (2) do not lead to whole numbers, (3) multiply each ratio by some integer (2, 3, etc.) to make all the ratios whole numbers.

1) Write formulas for the following:

a) bismuth nitrate
b) calcium hydride
c) mercury(II) cyanide
d) strontium iodide
e) tin(IV) hydroxide
f) potassium sulfite
g) sodium carbonate
h) cobalt(II) nitrite
i) chromium(III) iodide
j) zinc phosphate
k) magnesium carbonate
l) tin(II) chloride
m) lead(II) bromide
n) ammonium dichromate
o) nickel(II) chromate
p) cadmium cyanate
q) mercury(I) chloride
r) manganese(II) periodate
s) copper(II) oxide
t) lithium nitrate
u) aluminum sulfide
v) iron(II) phosphate
w) barium sulfate
x) silver nitrate
y) copper(I) sulfide
z) iron(III) sulfate

2) Calculate the percentage composition, by mass, of the following. Use four significant figures.

a) potassium phosphate
b) ammonium cyanide
c) sodium hydrogen sulfate
d) potassium perchlorate
e) zinc chloride
f) aluminum nitrate
g) chromium(III) hydroxide
h) copper(II) carbonate

3) Using the percentages from problem (2) calculate the following:

a) grams of phosphate in 65.5 g of potassium phosphate
b) milligrams of nitrogen in 250.0 mg of ammonium cyanide
c) pounds of sodium in 10.0 lbs of sodium hydrogen sulfate
d) grams of chlorine in 37.5 g of potassium perchlorate
e) tons of zinc in 15.25 tons of zinc chloride
f) tons of nitrate in 125 tons of aluminum nitrate
g) milligrams of oxygen in 1.500 g chromium(III) hydroxide
h) pounds carbon in 138 lbs copper(II) carbonate

4) Convert each of the following to moles:

a) 25.00 g of iron(III) sulfate
b) 3.67 x 10^{-2} g of lead(II) nitrate
c) 5.990 x 10^{3} g of tin(II) bromide
d) 0.07785 kg of ammonium chromate
e) 175 g of manganese(II) carbonate
f) 8.5 x 10^{-6} g of zinc oxide
g) 0.4670 mg of barium sulfate
h) 3.55 x 10^{5} mg of aluminum chloride

5) Calculate the mass (in grams) of each of the following:

a) 1.00 mol of barium sulfate
b) 2.550 mol of zinc nitrate
c) 0.155 mol of sodium hydrogen carbonate
d) 1.255 mol of potassium permanganate
e) 1.67 x 10^{-2} mol of sodium hydroxide
f) 4.990 x 10^{-4} mol of copper(I) chloride
g) 0.00585 mol of magnesium chloride
h) 1.45 x 10^{2} mol of calcium bromide

6) Calculate the following:

a) grams of manganese in 1.55 g of manganese(II) nitrate
b) tons of phosphorous in 5.73 tons of potassium phosphate
c) moles of sulfur in 7.33 g of aluminum sulfate
d) pounds of iron in 12.6 lbs of iron(II) phosphate
e) moles of nitrogen in 5.55 g of lead(II) nitrate
f) grams of nitrogen in 3.95 g of ammonium phosphate
g) grams of iron in 1.37 kg of iron(III) sulfide
h) moles of oxygen in 100.0 g of iron(III) sulfate

7) Calculate the following:

a) number of sodium atoms in 6.79 g of sodium metal
b) number of sodium ions in 7.77 g of sodium phosphate
c) number of water molecules in 15.5 mg of water
d) number of cobalt atoms in 111.1 mg of cobalt metal
e) number of ammonia molecules, NH_3, in 375 kg of ammonia
f) number of gold atoms in 1.00 x 10^{-6} mg of gold
g) number of ozone molecules, O_3, in 1.73 x 10^{-8} g of ozone
h) mass, in grams, of ten water molecules
i) mass, in grams, of one mercury atom
j) mass, in milligrams, of three sulfuric acid, H_2SO_4, molecules
k) mass, in kilograms, of 1.25 x 10^{15} sulfate ions
l) mass, in kilograms, of 2.57 x 10^{25} ammonium ions

8) Calculate the empirical formulas for the compounds with the following analyses:

a)	34.4% Fe	65.6% Cl		
b)	29.4% Ca	23.6% S	47.0% O	
c)	28.7% K	1.5% H	22.8% P	47.0% O
d)	28.0% Fe	24.1% S	48.0% O	
e)	88.8% Cu	11.2% O		
f)	72.3% Fe	27.7% O		
g)	69.9% Fe	30.1% O		
h)	11.1% N	3.2% H	41.3% Cr	44.4% O
i)	68.4% Cr	31.6% O		

Answers to Problems

1)

a)	$Bi(NO_3)_3$	h)	$Co(NO_2)_2$	o)	$NiCrO_4$	u)	Al_2S_3
b)	CaH_2	i)	CrI_3	p)	$Cd(CNO)_2$	v)	$Fe_3(PO_4)_2$
c)	$Hg(CN)_2$	j)	$Zn_3(PO_4)_2$	q)	Hg_2Cl_2	w)	$BaSO_4$
d)	SrI_2	k)	$MgCO_3$	r)	$Mn(IO_4)_2$	x)	$AgNO_3$
e)	$Sn(OH)_4$	l)	$SnCl_2$	s)	CuO	y)	Cu_2S
f)	K_2SO_3	m)	$PbBr_2$	t)	$LiNO_3$	z)	$Fe_2(SO_4)_3$
g)	Na_2CO_3	n)	$(NH_4)_2Cr_2O_7$				

2)

a)	55.26% K; 14.59% P; 30.15% O	for K_3PO_4
b)	63.59% N; 9.152% H; 27.26% C	for NH_4CN
c)	19.15% Na; 0.8396% H; 26.71% S; 53.30% O	for $NaHSO_4$
d)	28.22% K; 25.59% Cl; 46.19% O	for $KCl0_4$
e)	47.98% Zn; 52.02% Cl	for $ZnCl_2$
f)	12.67% Al; 19.73% N; 67.60% O	for $Al(NO_3)_3$
g)	50.47% Cr; 46.59% O; 2.935% H	for $Cr(OH)_3$
h)	51.43% Cu; 9.720% C; 38.85% O	for $CuCO_3$

3)

a)	29.3 g PO_4^{3-}	e)	7.317 tons Zn
b)	159.0 mg N	f)	109 tons NO_3^{1-}
c)	1.92 lbs Na	g)	698.8 mg O
d)	9.60 g Cl	h)	13.4 lbs C

4)
a) 0.06252 mol $Fe_2(SO_4)_3$
b) 1.11 x 10^{-4} mol $Pb(NO_3)_2$
c) 21.51 mol $SnBr_2$
d) 0.5122 mol $(NH_4)_2CrO_4$
e) 1.52 mol $MnCO_3$
f) 1.0 x 10^{-7} mol ZnO
g) 2.001 x 10^{-6} mol $BaSO_4$
h) 2.66 mol $AlCl_3$

5)
a) 233 g $BaSO_4$
b) 483.0 g $Zn(NO_3)_2$
c) 13.0 g $NaHCO_3$
d) 198.3 g $KMnO_4$
e) 0.668 g NaOH
f) 0.04940 g CuCl
g) 0.558 g $MgCl_2$
h) 2.90 x 10^4 g $CaBr_2$

6)
a) 0.476 g Mn in $Mn(NO_3)_2$
b) 0.837 ton P in K_3PO_4
c) 0.0642 mol S in $Al_2(SO_4)_3$
d) 5.90 lbs Fe in $Fe_3(PO_4)_2$
e) 0.0335 mol N in $Pb(NO_3)_2$
f) 1.11 g N in $(NH_4)_3PO_4$
g) 735 g Fe in Fe_2S_3
h) 3.001 mol O in $Fe_2(SO_4)_3$

7)
a) 1.78 x 10^{23} Na atoms
b) 8.56 x 10^{22} Na^{1+} ions in Na_3PO_4
c) 5.19 x 10^{20} H_2O molecules
d) 1.135 x 10^{21} Co atoms
e) 1.33 x 10^{28} NH_3 molecules
f) 3.06 x 10^{12} Au atoms
g) 2.17 x 10^{14} O_3 molecules
h) 2.992 x 10^{-22} g H_2O
i) 3.331 x 10^{-22} g Hg
j) 4.887 x 10^{-19} mg H_2SO_4
k) 1.99 x 10^{-10} kg SO_4^{2-}
l) 0.768 kg NH_4^{1-}

8)
a) $FeCl_3$
b) $CaSO_4$
c) KH_2PO_4
d) $Fe_2(SO_4)_3$
e) Cu_2O
f) Fe_3O_4
g) Fe_2O_3
h) $(NH_4)_2Cr_2O_7$
i) Cr_2O_3