Name:_____

Honors Chem: Types of Chemical Reactions

1.Explain how the process of balancing a chemical equation is necessary to satisfy the law of conservation of mass.

By balancing an equation, we make sure that every reactant atom is balanced by an equal number of product atoms. That way new substances are not created nor are substances destroyed in a chemical reaction.

2.Where do integral (whole) numbers appear in balanced chemical equations?

Whole numbers appear as coefficients preceding chemical formulas in chemical equations (2Zn). Whole numbers are also found as subscripts to denote the number of atoms (Br_2) of an element or the number of polyatomic ions $Zn(NO_3)_2$ in a formula. Whole numbers are also used as superscripts to indicate the charge on an atom (Ca^{2+}) or polyatomic molecule (SO_4^{2-}).

3. Which numbers can be changed to balance the equation?

Only the coefficients preceding a chemical formula can be changed.

4.In the following chemical equation

$$NaHCO_{3(s)} + H_3C_6H_5O_{7(aq)} \rightarrow 3CO_{2(g)} + 3H_2O_{(l)} + Na_3C_6H_5O_{7(aq)}$$

(i) What does the number *3* indicate in $3CO_{2(g)}$? What does the number *2* indicate? What does *(g)* mean?

3 is the number of molecules of CO_2 in the reaction
2 is the number of oxygen atoms in CO_2
(g) indicates the phase of the substance, in this case gaseous.

(ii) Identify the phase specified for each reactant and product.

$NaHCO_{3(s)}$ → solid
$H_2O_{(l)}$ → liquid
$CO_{2(g)}$ → gas
$H_3C_6H_5O_{7(aq)}$ → dissolved in water (a homogeneous aqueous solution)

(iii) Is the equation balanced? If not, write the balanced equation.

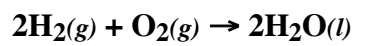
No

$$3NaHCO_{3(s)} + H_3C_6H_5O_{7(aq)} \rightarrow 3CO_{2(g)} + 3H_2O_{(l)} + Na_3C_6H_5O_{7(aq)}$$

5. Write a chemical equation illustrating each of the following reaction types. In each case, what are the important characteristics that could help you recognize other chemical equations as belonging to that particular category?

In the following problem the answers are likely to vary.

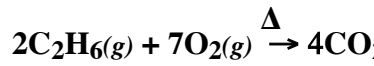
a) formation reaction



$2H_2(g) + O_2(g) \rightarrow 2H_2O(l)$

Formation reactions involve the formation of a compound from its elements in their standard state. Following the strict definition a formation reaction produces 1 mol of the product compound.

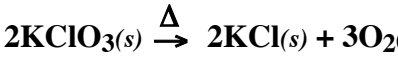
b) combustion reaction



$2C_2H_6(g) + 7O_2(g) \xrightarrow{\Delta} 4CO_2(g) + 6H_2O(g)$

A combustion reaction involves the reaction of oxygen, generally by heating a compound in air, with another compound. In the example provides oxygen reacts with a hydrocarbon. The products of this combustion reaction include carbon dioxide and water. Generally combustion products result from the combination of oxygen with the elements of the reacting compound.

c) decomposition reaction



$2KClO_3(s) \xrightarrow{\Delta} 2KCl(s) + 3O_2(g)$

A single substance is broken down into two or more substances generally as a result of adding heat.

d) single replacement reaction

$Zn_{(s)} + 2HCl_{(aq)} \rightarrow H_{2(g)} + ZnCl_{2(aq)}$

An element reacts with a compound to take the place of one of the elements of that compound. A different element and a different compound are formed. Common examples reactions include metals reacting with water or an acid. The element formed in these cases is hydrogen, H_2.

e) double replacement reaction

$BaCl_{2(aq)} + 2AgNO_{3(aq)} \rightarrow 2AgCl_{(s)} + Ba(NO_3)_{2(aq)}$

Precipitation reactions were the only example of double displacement reactions discussed. Precipitation reactions characteristically contain two reacting aqueous solutions of ionic substances. The products are obtained by trading ionic 'partners' forming two different compounds. One of the products is a precipitate.

f) neutralization reaction

$HCl_{(aq)} + NaOH_{(aq)} \rightarrow H_2O_{(l)} + NaCl_{(aq)}$

All neutralization reactions involve an acid and a base reacting to form a salt (which is composed of the cation of the base and anion of the acid) and water. To recognize a neutralization reaction all examples of acidic and basic compounds must be memorized.

6. Practice predicting the products of chemical reactions.

a) $2H_{2(g)} + O_{2(g)} \rightarrow 2\mathbf{H_2O_{(l)}}$

b) $C_2H_6O_{(l)} + 3O_{2(g)} \rightarrow \mathbf{2CO_{2(g)} + 3H_2O_{(l)}}$

c) $CaCO_{3(s)} \xrightarrow{\Delta} \mathbf{CaO_{(s)} + CO_{2(g)}}$

d) $Zn_{(s)} + 2HCl_{(aq)} \rightarrow \mathbf{ZnCl_{2(aq)} + H_{2(g)}}$

7.Define relative atomic mass unit (amu). What is the relationship between amu and the mass of a single atom expressed in grams?

amu (SI symbol is 'u') - a measure of atomic mass, defined as equal to $\frac{1}{12}$ the mass of a carbon atom of mass 12

$1\ u = 1.66056 \times 10^{-24}\ g$

$^{1}H = 1.008\ u \cdot \left(\frac{1.66056 \times 10^{-24}\ g}{1\ u}\right) = 1.67384 \times 10^{-24}\ g$

8.Describe how the formula mass of a compound is calculated.

The formula mass of a compound is calculated by summing the individual atomic masses of all the elements in the compound. For example, the formula mass of $Na_2Cr_2O_7$ is;

Formula mass = $2 \cdot A.M._{Na} + 2 \cdot A.M._{Cr} + 7 \cdot A.M._{O}$
Formula mass = $2 \cdot (23.0\ u) + 2 \cdot (52.0\ u) + 7 \cdot (16.0\ u) = 262\ u$

9.Define the terms *mole* and *Avogadro's number*. How are these two quantities related?

mol is the amount of the substance which contains the same number of units as 12 g of ^{12}C or 6.023×10^{23} units of the substance.

Avogadro's number - 6.022×10^{23}; It is the number of ^{12}C atoms in 12 g of ^{12}C

Thee are Avogadro's number (6.022×10^{23}) of particles in 1 mol of a substance.

10.Write a general mathematical equation that relates the number of moles of a compound to the molar mass of that compound.

moles of substance = $\frac{\text{gram of substance}}{\text{molar mass of substance}}$

Complete the following table

Formula	*M*, Molar Mass $\left(\frac{g}{mol}\right)$	*m*, Mass of sample (g)	*n*, Moles of sample (mol)	*N*, Number of atoms, molecules, or formula units
H_2SO_4	98.0	0.825	**0.00842**	**$5.07x\ 10^{21}$**
Cr_2O_3	**152**	**243**	**1.60**	9.63×10^{23}
unknown	**119.3**	56.8	0.476	**$2.87\ x\ 10^{23}$**
Mo	**95.9**	**$6.02\ x\ 10^{3}$**	62.8	**$3.78\ x\ 10^{25}$**

11. Briefly describe what information is contained in the formula of a compound. What initial information must be available to determine the empirical formula for a compound?

The formula of a compound provides the mol ratio of the elements contained within the compound.

1) The number of grams, moles or atoms of each element.

or 2) The percent composition of the compound. (I assume students can do this type of problem without an example in lecture.)

12a. Elemental analysis of nicotine reports 2.13 g carbon, 0.248 g hydrogen and 0.493 g nitrogen. Determine the simplest (empirical) formula for nicotine.

Solution:

Since a formula is a mol ratio of the elements we must convert these amounts to moles.

$$\mathbf{2.13\ g\ C\left(\frac{1\ mol\ C}{12.0\ g}\right) = 0.178\ mol\ of\ C\ atoms}$$

$$\mathbf{0.248\ g\ H\left(\frac{1\ mol\ H}{1.01\ g}\right) = 0.246\ mol\ of\ H\ atoms}$$

$$\mathbf{0.493\ g\ N\left(\frac{1\ mol\ N}{14.0\ g}\right) = 0.0352\ mol\ of\ nitrogen\ atoms}$$

The ratio for these three elements is,

0.178 mol of C atoms: 0.246 mol of H atoms: 0.0352 mol of N atoms

dividing through by the smallest number we can get whole numbers

5.06 C : 6.99 H : 1 N

the empirical formula for nicotine is C_5H_7N.

12b A 0.00300 g sample of napthalene, a compound containing only carbon and hydrogen, was burned in excess oxygen to give 0.0103 g of CO_2. Determine the empirical formula of napthalene. The formula weight of napthalene is 128 u, determine the molecular formula.

$$\mathbf{0.0103\ g\ CO_2 \left(\frac{1\ mol\ CO_2}{44.0\ g}\right) = 2.34 \times 10^{-4}\ mol\ of\ CO_2}$$

$$\mathbf{2.34 \times 10^{-4}\ mol\ of\ CO_2 \left(\frac{1\ mol\ C}{1\ mol\ CO_2}\right) = 2.34 \times 10^{-4}\ mol\ C}$$

$$\mathbf{2.34 \times 10^{-4}\ mol\ C \left(\frac{12.0\ g}{1\ mol\ C}\right) = 0.00281\ g\ C}$$

$$\mathbf{0.0030\ g - 0.00281\ g\ C = 1.9 \times 10^{-4}\ g\ H}$$

$$\mathbf{1.9 \times 10^{-4}\ g\ H \left(\frac{1\ mol\ H}{1.008\ g}\right) = 1.9 \times 10^{-4}\ mol\ of\ H}$$

2.34 x 10^{-4} mol C : 2 x 10^{-4} mol of H

1.24 C : 1 H multiply by 4 to get whole numbers

C_5H_4 is the empirical formula for napthalene. The empirical mass is 64 u, and the formula mass is 128 u.

The molecular formula is related to the empirical formula according to the relationship;

$$\mathbf{(empirical\ formula)_n = molecular\ formula}$$

where n is the ratio of the molecular mass to the empirical mass.

$$\mathbf{n = \frac{molecular\ mass}{empirical\ mass} = \frac{128}{64} = 2}$$

$$\mathbf{(C_5H_4)_2 = C_{10}H_8}$$

13.Determine the number of moles in each of the following.

a) 25.6 g of acetic acid ($HC_2H_3O_2$)

$$\mathbf{25.6\ g\ HC_2H_3O_2 \left(\frac{1\ mol\ HC_2H_3O_2}{60.0\ g}\right) = 0.427\ mol\ HC_2H_3O_2}$$

b) 1.89 x 10^{-4} g of $Ca_3(PO_4)_2$

$$\mathbf{1.89 \times 10^{-4}\ g\ Ca_3(PO_4)_2 \left(\frac{1\ mol\ Ca_3(PO_4)_2}{310.\ g}\right) = 6.10 \times 10^{-7}\ mol\ Ca_3(PO_4)_2}$$

14.Determine the number of oxygen atoms in each of the following.

a) 6.451 moles of $C_6H_8O_6$ (vitamin C)

$$\mathbf{6.451\ mol\ C_6H_8O_6 \left(\frac{6.023 \times 10^{23}\ molecules}{1\ mol\ C_6H_8O_6}\right)\left(\frac{6\ mol\ O\ atoms}{1\ molecule\ C_6H_8O_6}\right) = 2.331 \times 10^{25}\ O\ atoms}$$

b) 1.89 x 10^{-4} g of $Ca_3(PO_4)_2$

$$\mathbf{6.10 \times 10^{-7}\ mol\ Ca_3(PO_4)_2 \left(\frac{6.023 \times 10^{23}\ f.u.}{1\ mol\ Ca_3(PO_4)_2}\right)\left(\frac{8\ mol\ O\ atoms}{1\ f.u.\ Ca_3(PO_4)_2}\right) =}$$

$$\mathbf{2.94 \times 10^{18}\ O\ atoms}$$

15. Determine the mass in grams in each of the following.

a) 0.0721 moles of H_3PO_4 (phosphoric acid)

$$\mathbf{0.0721\ mol\ H_3PO_4}\left(\frac{\mathbf{98.0\ g\ H_3PO_4}}{\mathbf{1\ mol}}\right) = \mathbf{7.07\ g\ H_3PO_4}$$

b) 72 atoms of sulfur

$$\mathbf{72\ atoms\ S}\left(\frac{\mathbf{1\ mol\ S}}{\mathbf{6.02 \times 10^{23}\ atoms}}\right)\left(\frac{\mathbf{32.1\ g\ S}}{\mathbf{1\ mol}}\right) = \mathbf{3.8 \times 10^{-21}\ g\ S}$$

16. Determine the percent composition of each element in $Ni_3(PO_4)_2$.

Molar mass of $Ni_3(PO_4)_2$ = 3 x 58.7 = 176 g

2 x 31.0 = 62.0 g

8 x 16.0 = 128 g

Total = 366 g

$$\mathbf{\%\ Ni} = \frac{\mathbf{mass\ Ni}}{\mathbf{mass\ Ni_3(PO_4)_2}} \mathbf{\times 100} = \frac{\mathbf{176\ g}}{\mathbf{366\ g}} \mathbf{\times 100 = 48.1\ \%\ Ni}$$

$$\mathbf{\%\ P} = \frac{\mathbf{62.0\ g}}{\mathbf{366\ g}} \mathbf{\times 100 = 16.9\ \%\ P} \qquad \mathbf{\%\ O} = \frac{\mathbf{128.0\ g}}{\mathbf{366\ g}} \mathbf{\times 100 = 35.0\ \%\ O}$$

17. Determine the empirical formula for a compound which is 26.6 % potassium, 35.4 % chromium and 38.1 % oxygen.

Assume 100 g of the compound

$$\mathbf{26.6\ g\ K}\left(\frac{\mathbf{1\ mol\ K}}{\mathbf{39.1\ g}}\right) = \mathbf{0.680\ mol\ K}$$

$$\mathbf{35.4\ g\ Cr}\left(\frac{\mathbf{1\ mol\ Cr}}{\mathbf{52.0\ g}}\right) = \mathbf{0.681\ mol\ Cr}$$

$$\mathbf{38.1\ g\ O}\left(\frac{\mathbf{1\ mol\ O}}{\mathbf{16.0\ g}}\right) = \mathbf{2.38\ mol\ O}$$

$$\frac{\mathbf{0.680\ mol\ K}}{\mathbf{0.680\ mol}} : \frac{\mathbf{0.681\ mol\ Cr}}{\mathbf{0.680\ mol}} : \frac{\mathbf{2.38\ mol\ O}}{\mathbf{0.680\ mol}} =$$

$$\mathbf{1\ K : 1\ Cr : 3.5\ O = K_2Cr_2O_7}$$

18. When a solid compound which is 27.62 % Ca, 22.06 % S, 49.62 % O and 0.700 % H is heated, a solid product is isolated which is 29.45 % Ca, 23.52 % S and 47.03 % O. What is the other product formed? Write the chemical equation which describes the reaction which has occurred.

Formula of the reactant:

$$\mathbf{27.62\ g\ Ca}\left(\frac{\mathbf{1\ mol\ Ca}}{\mathbf{40.08\ g}}\right) = \mathbf{0.6891\ mol\ Ca}$$

$$\mathbf{22.06\ g\ S}\left(\frac{\mathbf{1\ mol\ S}}{\mathbf{32.06\ g}}\right) = \mathbf{0.6881\ mol\ S}$$

$$\mathbf{49.62\ g\ O}\left(\frac{\mathbf{1\ mol\ O}}{\mathbf{16.00\ g}}\right) = \mathbf{3.101\ mol\ O}$$

$$0.700 \text{ g H}\left(\frac{1 \text{ mol H}}{1.01 \text{ g}}\right) = 0.693 \text{ mol H}$$

$$\frac{0.6891 \text{ mol Ca}}{0.6881 \text{ mol}} : \frac{0.6881 \text{ mol S}}{0.6881 \text{ mol}} : \frac{3.101 \text{ mol O}}{0.6881 \text{ mol}} : \frac{0.693 \text{ mol H}}{0.6881 \text{ mol}}$$

$$1 \text{ Ca} : 1 \text{ S} : 4.5 \text{ O} : 1 \text{ H} = 2 \text{ Ca} : 2 \text{ S} : 9 \text{ O} : 2 \text{ H}$$

$$Ca_2S_2O_9H_2 \quad [(CaSO_4)_2 \bullet H_2O]$$

Formula of the product:

$$29.45 \text{ g Ca}\left(\frac{1 \text{ mol Ca}}{40.08 \text{ g}}\right) = 0.7348 \text{ mol Ca}$$

$$23.52 \text{ g S}\left(\frac{1 \text{ mol S}}{32.06 \text{ g}}\right) = 0.7336 \text{ mol S}$$

$$47.03 \text{ g O}\left(\frac{1 \text{ mol O}}{16.00 \text{ g}}\right) = 2.94 \text{ mol O}$$

$$\frac{0.7348 \text{ mol Ca}}{0.7336 \text{ mol}} : \frac{0.7336 \text{ mol S}}{0.7336 \text{ mol}} : \frac{2.94 \text{ mol O}}{0.7336 \text{ mol}}$$

$$1 \text{ Ca} : 1 \text{ S} : 4 \text{ O}$$

$$CaSO_4$$

The other product is water and the reaction is

$$(CaSO_4)_2 \cdot H_2O \rightarrow 2\ CaSO_4 + H_2O$$