Chem 1032 Stoichiometry Review

Stoichiometry

Fundemental to understanding the nature of matter and how it intereacts with each other, we must be conscience of the fact that matter is conserved in all cases. Consider the below reaction;

$$XCH_3OH + YO_2 -> ACO_2 + BH_2O$$

In order for the conservation of matter to hold, we would need to balance the chemical reaction. Balancing means that there are the same number of each element on both the products and reactants side, calculated by the mole coefficients and subscripts. We would do so by counting up the number of moles of each element in the equation, and then figuring out the smallest combination of mole coefficients (*X,Y,A,B*) that would give us equal moles of each element on each side. One method to do so may be making a table;

Element	Reactant	Products
C	1	1
O	3	3
H	4	2

So it would seem we need to multiply the **H_2O** on the products side by **2**, giving us **4 H**'s, but now that increases our **O**'s to **4**;

$$XCH_3OH + YO_2 -> ACO_2 + 2H_2O$$

Element	Reactant	Products
C	1	1
O	3	4
H	4	4

to balance the **O**'s we multiply the **CH_3OH** by **2** giving us ;

$$2CH_3OH + YO_2 -> ACO_2 + 2H_2O$$

Element	Reactant	Products
C	2	1
O	4	4
H	8	4

Now we have **8 H**'s and **2 C**'s, we can multiply our **CO_2** by **2**, giving us **2 C**'s, **6 O**'s, and **4 H**'s on the product side;

$$2CH_3OH + YO_2 -> 2CO_2 + 2H_2O$$

Element	Reactant	Products
C	2	2
O	4	6
H	8	4

to balance the **H**'s on the products side we can double our current moles of **H_2O** to **4** and on the reactants side multiply the **O_2** by **3**, yielding a balanced chemical reaction;

$$2CH_3OH + 3O_2 -> 2CO_2 + 4H_2O$$

Element	Reactant	Products
C	2	2
O	8	8
H	8	8

Now that we have balanced the reaction, let's say I gave you 50 mL of MeOH (CH_3OH) and asked you to predict how much CO_2 would evolve from the reaction? You would have to use dimensional analysis in combination with stoichiometry to approach this problem. Dimensional analysis is the process of using relations between different units to interconvert them.

Starting with 50mL of MeOH, we would have to use the density of MeOH (0.791 g/mL) to convert to mass, then from mass, convert to moles, then using the 2:2 or 1:1 relationship between MeOH and CO_2, we can figure out how much CO_2 would evolve from this reaction;

$$50mL_{MeOH} x \frac{0.791g_{MeOH}}{1mL_{MeOH}} x \frac{1mol_{MeOH}}{32g_{MeOH}} x \frac{1mol_{CO_2}}{1mol_{MeOH}}$$

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If we have done everything correctly, all of our units should cancel

$$50 \cancel{mL}_{MeOH} x \frac{0.791 \cancel{g}_{MeOH}}{1 \cancel{mL}_{MeOH}} x \frac{1 \cancel{mol}_{MeOH}}{32 \cancel{g}_{MeOH}} x \frac{1mol_{CO_2}}{1 \cancel{mol}_{MeOH}} = 1.2\ mol_{CO_2}$$

A few additional questions to consider regarding this problem;

Assuming balloon is placed over the reaction vessel, how much volume does the evolved CO_2 occupy at $25C^o$ and 1 atm (hint:PV=nRT)? What is the mass of the CO_2 evolved?

What volume of water is produced from this reaction? Say that I recovered 36.598 g of water after this reaction, how would that amount compare to the theoretical amount (hint: $\%yield = \frac{actualyield}{theoreticalyield} x100$)?

Additional Problems:

1.) Write a balanced molecular equation describing each of the following chemical reactions.

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(a) Solid calcium carbonate is heated and decomposes to solid calcium oxide and car
bon dioxide gas.

(b) Gaseous butane, C4H10, reacts with diatomic oxygen gas to yield gaseous carbon
 dioxide and water vapor.

(c) Aqueous solutions of magnesium chloride and sodium hydroxide react to produce s
olid magnesium hydroxide and aqueous sodium chloride.

(d) Water vapor reacts with sodium metal to produce solid sodium hydroxide and hydr
ogen gas.
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2.) Colorful fireworks often involve the decomposition of barium nitrate and potassium chlorate and the reaction of the metals magnesium, aluminum, and iron with oxygen.

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(a) Write the formulas of barium nitrate and potassium chlorate.

(b) The decomposition of solid potassium chlorate leads to the formation of solid p
otassium chloride and diatomic oxygen gas. Write an equation for the reaction.

(c) The decomposition of solid barium nitrate leads to the formation of solid bariu
m oxide, diatomic nitrogen gas, and diatomic oxygen gas. Write an equation for the
 reaction.

(d) Write separate equations for the reactions of the solid metals magnesium, alumi
num, and iron with diatomic oxygen gas to yield the corresponding metal oxides. (As
sume the iron oxide contains Fe3+ ions.)
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3.) Write the balanced equation, then outline the steps necessary to determine the information requested in each of the following:

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(a) The number of moles and the mass of chlorine, Cl2, required to react with 10.0
 g of sodium metal, Na, to produce sodium chloride, NaCl.

(b) The number of moles and the mass of oxygen formed by the decomposition of 1.252
g of mercury(II) oxide.

(c) The number of moles and the mass of sodium nitrate, NaNO3, required to produce
 128 g of oxygen. (NaNO2 is the other product.)

(d) The number of moles and the mass of carbon dioxide formed by the combustion of
 20.0 kg of carbon in an excess of oxygen.

(e) The number of moles and the mass of copper(II) carbonate needed to produce 1.50
0 kg of copper(II) oxide. (CO2 is the other product.)
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4.) What mass of silver oxide, Ag2O, is required to produce 25.0 g of silver sulfadiazine, $AgC_{10}H_9N_4SO_2$, from the reaction of silver oxide and sulfadiazine?

$$2C_{10}H_{10}N_4SO_2 + Ag_2O \longrightarrow 2AgC_{10}H_9N_4SO_2 + H_2O$$

5.) Urea, $CO(NH_2)_2$, is manufactured on a large scale for use in producing urea-formaldehyde plastics and as a fertilizer. What is the maximum mass of urea that can be manufactured from the CO_2 produced by combustion of 1.00×103kg of carbon followed by the reaction?

$$CO_{2(g)} + 2NH_{3(g)} \longrightarrow CO(NH_2)_{2(s)} + H_2O_{(l)}$$

6.)The following quantities are placed in a container: 1.5 × 1024 atoms of hydrogen, 1.0 mol of sulfur, and 88.0 g of diatomic oxygen.

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(a) What is the total mass in grams for the collection of all three elements?

(b) What is the total number of moles of atoms for the three elements?

(c) If the mixture of the three elements formed a compound with molecules that cont
ain two hydrogen atoms, one sulfur atom, and four oxygen atoms, which substance is
 consumed first?

(d) How many atoms of each remaining element would remain unreacted in the change d
escribed in (c)?
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Recall

$$1\ mol = 6.022x10^{23}\ atoms$$

$$R = 8.314\frac{J}{mol \cdot K} = 8.314x10^{-2}\frac{L \cdot bar}{mol \cdot K}$$

$$1\ atm = 1.01325\ bar$$