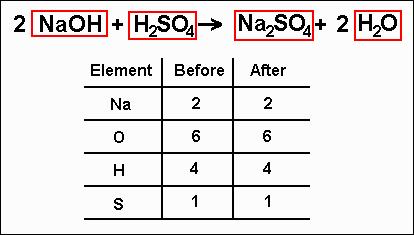
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**Topic #10**

***BALANCING EQUATIONS***

***&***

**STOICHIOMETRY**



**Homework Due: \_\_\_\_\_\_\_\_\_\_\_\_\_\_**

**Exam Dates:**

**Free Response: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**

**Multiple Choice: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**

**MCj01405810000[1]**

Balancing Chemical Equations

***# of atoms of each element on each side of equation must be equal. Remember it must follow Law of Conservation of mass.***

# ***Rules to use for balancing equations***

**Remember the tricks:**

* Water trick
* polyatomic ions
* Common denominator FIRST!!!!
* Substances in 2 places on one side of equation

**Here are some suggestions….**

1. **Single element in the largest compound**

- Pick out the compound with the most atoms (magnesium phosphate).

- Choose an element within the compound that is not hydrogen or oxygen.

- Do not pick the polyatomic ion initially.

- This leaves magnesium. Balance magnesium first by placing a 3 in front of magnesium hydroxide.

**3Mg(OH)2 + H3PO4 -----> Mg3(PO4)2 + H2O**

**We now have 3 atoms of magnesium on both sides**.

1. **Polyatomic ions**

- Next, balance the ***polyatomic ions*** that remain the same on both sides.

- We have phosphate on both the left and right side. In order to balance the phosphate, place a 2 in front of phosphoric acid.

**3Mg(OH)2 + 2 H3PO4 ------> Mg3(PO4)2 + H2O**

**3**. **Hydrogen and oxygen atoms**

- Balance the *hydrogen* (H) atoms and then the *oxygen* (O) atoms.

- On the reactant side, we have 6 hydrogen atoms in magnesium hydroxide and 6 hydrogen atoms in phosphoric acid for a total of 12 hydrogen atoms.

- By placing a 6 in front of the water molecule, hydrogen is balanced.

- By doing this, the oxygen atoms are also balanced, 6 on each side.

**3Mg(OH)2 + 2 H3PO4 -----> Mg3(PO4)2 + 6 H2O**

1. **Whole number coefficients and lowest ratio**

Make sure that the coefficients used are all whole numbers and that the coefficients are reduced to their lowest terms. In this case, it is not a problem.

|  |  |
| --- | --- |
| Check each atom or polyatomic ion on both sides of the equation to make sure that the equation is balanced.  **Reactants** | **Products** |
| 3 magnesium (Mg) | 3 magnesium |
| 2 phosphates (PO4) | 2 phosphates |
| 12 hydrogen (H) | 12 hydrogen |
| 6 oxygen (O) | 6 oxygen |

**5. Recheck**

**The equation is now balanced.**

**Stoichiometry**

There are two ways of approaching this area:

A) Dimensional Analysis

B) Box method when comparing different units

*Ex: 1 Dimensional Analysis*

*Dimensional analysis* is a mathematical system using conversion factors to move from one unit of measurement to a different unit of measurement. For example, if you need to calculate how many seconds are in a day, you can use dimensional analysis to set all of your needed conversions into one problem.

**For example: *Converting 1 day into seconds***

1 day x 24 hours x 60 minutes x 60 seconds = 86,400 seconds

   1 day           1 hour          1 minute

**1 day = 86,400 seconds**

Conversion factors and dimensional analysis make comparing different units much easier.

Using Dimensional Analysis to solve a mole –mole problem

***Find the number of moles of H2 needed to react with 4.3 moles of O2 to make water***

?moles 4.3moles

2H2 + O2 🡪 2H2O

4.3 moles O2 x 2 moles H2  = 8.6 moles H2

1 mole O2

*Ex: 2 BOX METHOD*

1. Change given amount to moles ( use the mole wheel)
2. Change moles of given to moles of unknown using the coefficient ratio. Your box has it set up correctly
3. Change new found mole amount in #2 to whatever unit they want. Use mole wheel or factor label for steps 1 and 3.

***How many grams of water will be produced when 88 liters of C2H6***

***is used?***

88liters ?grams

2 C2H6  + 7O2 🡪 4CO2 + 6H2O

88 9 x 18g (mass of H2O)

22.4

3moles = 2 x = 9 moles

X 6

**Section I: What is a Balanced Equation?**

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**6.** Chemical equations can be described in the following quantities: numbers of atoms; molecules, or moles; mass; and volumes.

**8.** Mass and atoms are quantities that are always conserved in chemical reactions.

**9. Interpret the equation in terms of…**

|  |
| --- |
| **Representative Particles:**  2 atoms K + 2 molecules H2O 🡪 2 formula units KOH + 1 molecule H2 |
| **Numbers of Moles:**  2 mol K + 2 mol H2O 🡪 2 mol KOH + 1 mol H2 |
| **Masses of Reactants and Products:**  78.2 g K + 36.0 g H2O 🡪 112.2 g KOH + 2.0 g H2 |

**10. Balanced Equation:** C2H5OH + 3O2 🡪 2CO2 + 3H2O

**Masses of Reactants**: 46.0 g C2H5OH + 96.0 g 3O2 = 142.0 of reactants

**Masses of Products**: 88.0 g CO2 + 54.0 g 3H2O = 142.0 of products

**Evidence for Law of Conservation of Mass:**

**Mass of reactants:** 142.0 **g = Mass of products:** 142.0 **g**

**Section II: Practice Balancing Chemical Equations**

**Balance the following equations.(remember the tricks!!)**

1) 2 NaNO3 + \_\_\_ PbO 🡪 \_\_\_ Pb(NO3)2 + \_\_\_ Na2O

Hint: Keep the polyatomic ions together.

2) \_\_\_ C2H4O2 + 2 O2 🡪 2 CO2 + 2H2O

Hint: Balance out the oxygen atoms last.

3) \_\_\_ ZnSO4 + \_\_\_ Li2CO3 🡪 \_\_\_ ZnCO3 + \_\_\_ Li2SO4

4) \_\_\_ V2O5 + 5 CaS 🡪 5 CaO + \_\_\_ V2S5

5) 6 AgI + \_\_\_\_Fe2(CO3)3 -----> 2 FeI3 + 3 Ag2CO3

Hint: Use a common denominator (6)

6) 3 H2SO4 + 2 B(OH)3 🡪 \_\_ B2(SO4)3 + 6 H2O

Hint: Use the water trick H2O -> H(OH)

7) \_\_\_ S8­ + 8 O2 🡪 8 SO2

**Section III: Predicting Products & Balancing Chemical Equations**

Complete and balance the following decomposition reactions:

1. 2OF2 ----> O2 + 4F2
2. 2 HI ----> H2 + I2

Complete and balance the following single replacement reactions:

a. F2 + 2NaBr ----> 2NaF + Br2

b. 2Al + 3 CuSO4 -----> Al2(SO4)3 + 3Cu

Complete and balance the following double replacement reactions:

a. CdBr2 + Na2S ----> 2NaBr + CdS

b. 3Ba(NO3)2 + 2 H3PO4 ----> Ba3(PO4)2 + 6HNO3

**Section IV: Writing & Using Mole Ratios**

Remember: Mole ratios are used to convert from the amount of one substance to amount of another substance

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**11a.**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **4 mol Al**  **3 mol O2** | **3 mol O2**  **4 mol Al** | **4 mol Al**  **2 mol Al2O3** | **2 mol Al2O3**  **4 mol Al** | **3 mol O2**  **2 mol Al2O3** | **2 mol Al2O3**  **3 mol O2** |

**11b.*Show all work.***

3.7 mol Al2O3 x 4 mol Al = 7.4 mol Al

2 mol Al2O3

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45. 5C(s) + 2SO2(g) 🡪 CS2(l) + 4CO(g)

a) 2.7 mol C x 1 mol CS2 = 0.54 mol CS2

5 mol C

b) 5.44 mol SO2 x 5 mol C = 13.6 mol C

2 mol SO2

c) 0.246 mol CS2 x 4 mol CO = 0.984 mol CO

1 mol CS2

d) 118 mol CS2 x 2 mol SO2 = 236 mol SO2

1 mol CS2

46. **CO(g) + 2H­2(g) 🡪 CH3OH(g)**

a) 2.7 mol C x 1 mol CS2 = 0.54 mol CS2

5 mol C

b) 5.44 mol SO2 x 5 mol C = 13.6 mol C

2 mol SO2

49)

12.0 g Fex 1 mol Fe x 2 mol Fe2O3 x159.69gFe2O3 = 17.2 g Fe2O3

55.845 g Fe 4 mol Fe 1 mol Fe2O3

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68) 1.40 L O2(g) x 4 L NO(g) = 1.12 L NO(g)

5 L O2(g)

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84) Moles of reactants might combine, recombine in different ratios, or decompose into components. Therefore, a mole of reactant do not necessarily translate into a mole of product.

**Section V: Stoichiometry Practice Problems**

**Complete the following stoichiometry problems. Must show all work.**

1. In a spacecraft, the carbon dioxide exhaled by astronauts can be removed by its reaction with lithium hydroxide, according to the following chemical equation.

**CO2(g) + 2LiOH(s) ----> Li2CO3(s) + H2O(l)**

How many moles of lithium hydroxide are required to react with 20 moles of carbon dioxide, the average amount exhaled by a person each day?

20 mol CO2 x 2 mol LiOH = 40 mol LiOH

1 mol CO2

**Section V: Stoichiometry Practice Problems (continued)**

1. In photosynthesis, plants use energy from the sun to produce glucose, C6H12O6, and oxygen from the reaction of carbon dioxide and water.

**6CO2(g) + 6H2O(l) ----> C6H12O6(s) + 6O2(g)**

1. What mass, in grams, of glucose is produced when 3.00 moles of water react with carbon dioxide?

3.00 mol H2O x 1 mol C6H12O6 x 180.0 g C6H12O6 = 90.0 g

6 mol H2O 1 mol C6H12O0

1. What mass of carbon dioxide, in grams, is needed to react with 3.00 mole of water?

3.00 mol H2O x 6 mol CO2 x 44.0 g CO2 = 132.0 g CO2

6 mol H2O 1 mol CO2

1. The first step in the industrial manufacture of nitric acid is the catalytic oxidation of ammonia. The reaction is run using 824 grams NH3 and excess oxygen. How many moles of water are formed?

**4NH3(g) + 5O2(g) ----> 4NO(g) + 6H2O(g)**

824 g NH3 x 1 mol NH3 x 6 mol H2O = 72.7 mol H2O

17.0 g NH3 4 mol NH3

1. Given the following equation:

**Cu + 2 AgNO3 ---> Cu(NO3)2 + 2 Ag**

If 89.5 grams of Ag were produced, how many grams of Cu reacted?

89.5 g Ag x 1 mol Ag x 1 mol Cu x 63.5 g Cu = 26.3 g Cu

108. g Ag 2 mol Ag 1 mol Cu

**Section V: Stoichiometry Practice Problems (cont.)**

**Putting it all together:**

1. Acetylene gas, C2H2, is produced by adding water to calcium carbide,

CaC2.

**CaC2(s) + 2H2O(l) ----> C2H2 (g) + Ca(OH)2(aq)**

1. How many mol of CaC2 are needed to react completely with 49.0 g of H2O?

49.0 g H2Ox 1 mol H2O x 1 mol CaC2 = 1.36 mol CaC2

18.0 g H2O 2 mol H2O

1. How many moles of acetylene gas are produced when 3.75 moles of calcium carbide is used.

3.75 mol CaC2 x 1 mol C2H2 = 3.75 mol C2H2

1 mol CaC2

1. How many grams of calcium hydroxide are produced when 24 g of C2H2  is produced?

24 g C2H2 x 1 mol C2H2 x 1 mol Ca(OH)2 x 74 g Ca(OH)2 = 68.3 g

26.0 g C2H2 1 mol C2H2 1mol Ca(OH)2

1. How could you prove that this equation obeys the law of conservation of mass?

Using the balanced equation, compare the total mass of the reactants to the total mass of the products. Both sides should have the same total mass.

**Gas Stoichiometry Practice**

*For all of these problems, assume that the reactions are being performed at STP.*

1) Calcium carbonate decomposes at high temperatures to form carbon dioxide and calcium oxide:

**CaCO3(s) 🡪 CO2(g) + CaO(s)**

How many grams of calcium carbonate will I need to form 3.45 liters of carbon dioxide?

3.45 L CO2 x 1 mol CO2 x 1 mol CaCO3 x 100.0 g CaCO3 = 15.4 g

22.4 L CO2 1 mol CO2 1 mol CaCO3

2) Ethylene burns in oxygen to form carbon dioxide and water vapor:

**C2H4(g) + 3 O2(g) 🡪 2 CO2(g) + 2 H2O(g)**

How many liters of water can be formed if 7.25 liters of ethylene are consumed in this reaction?

7.25 L C2H4 x 2 L H2O = 14.50L H2O

1 L C2H4

**Stoichiometry Critical Thinking Skills**

Camels store the fat tristearin (**C57H110O6**) in the hump. Besides being a source of energy, the fat is a source of water for the camel because when the fat is burned, the following reaction occurs:

**2 C57H110O6(s) + 163 O2(g) 🡪 114 CO2(g) + 110 H2O(l)**

a. At STP, what volume of oxygen is required to consume 0.75mol

of tristearin?

0.75 mol C57H110O6 x 163mole O2 = 61.1 moles x 22.4L/mol= 1389.2L

2 mole C57H110O6

b. At STP, what volume of carbon dioxide is produced in Part A?

0.75 mol C57H110O6 x 114 mol CO2 x 22.4 L = 957.6L

2 mol C57H110O6 1 mol CO2

1. If 32.4 L of oxygen is consumed at STP, how many moles of water are produced?

32.4 L O2 x 1 mol O2 x 110 mol H2O = .98 mol H2O

22.4 L 163 mol O2

1. Find the mass of tristearin required to produce 55.56 moles of water.

55.56 mol H2O x 2 mol C57H110O6  x 890 g C57H110O6 = 989.7 g

110 mol H2O 1 mol C57H110O6

**LIMITING REACTANTS READING ASSIGNMENT**

Most cooks follow a recipe when making a new dish. Sufficient quantities of all the ingredients must be available. For example, in preparing to make lasagna you find that you have more than enough meat, tomato sauce, ricotta cheese, eggs, mozzarella cheese and seasonings on hand. In fact, the noodles are the ***limiting reactant.*** The amount of noodles available will determine how many trays of lasagna can be made. A chemist often faces a similar situation. It is impossible for a chemist to make a certain amount of a desired compound if there is an insufficient quantity of any of the required reactants. Meaning, the amount of product is limited by the quantity of the limiting reagent. In summary, no matter how much of the ingredients you have to make trays of lasagna, with only one box of noodles you can only make one tray of lasagna.

Remember: **A balanced chemical equation is a chemist’s recipe.**

Consider the following synthesis reaction:

**2 Al + 3 I2 ------> 2 AlI3**

Let’s suppose there is 1.20 mol of aluminum and 2.40 mol of iodine available in the laboratory. The student wants to determine the limiting reagent and the theoretical yield of aluminum iodide formed.

To determine the limiting reagent, take the moles of each substance and divide it by the coefficient of the balanced equation. The substance that has the ***smallest answer*** is the **limiting reactant**.

Meaning,

**Al : 1.20 mol / 2 = 0.60  
 I2: 2.40mol / 3 = 0.80**

The limiting reagent is ***aluminum*** and will run out first in this reaction. Why? 1.20/2 means there are 0.60 "groupings" of 2 and 2.40/3 means there are 0.80 "groupings" of 3. If they ran out at the same time, we'd need one "grouping" of each. Since there is less of the "grouping of 2," it will run out first. The **excess reactant** is iodine because it will not be used up completely in the reaction.

The "**theoretical yield**" depends on finding out the limiting reagent. Once we do that, it becomes a stoichiometric calculation. Al and AlI3 stand in a one-to-one mole relationship, so **1.20 mol** of **Al** produces **1.20 mol** of **AlI3.** Notice that the amount of I2 does not play a role, since it is in excess. In other words, the starting amount of the limiting reactant (1.20 mol of Al) determines the amount of product formed (theoretical yield).

**Questions:**

**Define the following terms:**

**Limiting reactant:**

**In a chemical reaction, the limiting reagent, also known as the "limiting reactant", is the substance, which is totally consumed when the chemical reaction is complete. This reagent limits the amount of product formed since the reaction cannot proceed further without it**

**Excess reactant:**

**The excess reactant is the reactant in a chemical reaction with greater amount than necessary to react completely with the limiting reactant**.

**Theoretical Yield:**

**In chemistry, yield, also referred to as a reaction yield, is the amount of product obtained in a chemical reaction. The absolute yield can be given as the weight in grams or in moles.**

**Problem: Show all Work**

Some rocket engines use a mixture of hydrazine, N2H4, and hydrogen peroxide, H2O2, as the propellant. The reaction is given by the following equation: **N2H2(l) + 2H2O2(l) ----> N2(g) + 4H2O(g)**

1. Which is the limiting reactant in this reaction when 0.750 mol N2H2 is mixed with 0.500 mol H2O2?

0.750 mol N2H2  = 0.750 mol 0.500 mol H2O2 = **.25 mol**

1 mol N2H2 2 mol H2O2

**H2O2 is the limiting reactant.**

1. How much of the excess reactant, in moles, remains unchanged?

0.500mol H2O2 x 1 mol N2H2 = 0.250 mol N2H2 is used.

2 mol H2O2

Therefore,

**0.750 mol - .0.250 mol = .500 mol remains unchanged.**

1. How much of each product, in moles, is formed?

0.500 mol H202 x 1 mol N2 = **0.25 mol N2**

2 mol H2O2

0.500 mol H2O2  x 4 mol H2O = **1 mol H2O**

2 mol H2O2

d. How much of each product, in grams, is formed?

.25 mol N2 x 28.0 g N2 = **7 grams N2 , 1mole H2O = 18 grams**

1 mole