Physical Science 20
Stoichiometry (Calculations involving Reactions) (7)

Calculations involving reactions

- An equation is a statement which expresses info about reactants and products
- You need specific ingredients and specific amounts of ingredients (like a recipe)
  - Ex. Doubling the ingredients doubles the results
- YOU GET OUT WHAT YOU PUT IN!
- Ex: Combination of Calcium and Oxygen

  $2\ Ca + O_2 \rightarrow 2CaO$

  - This is the balanced equation. It also holds true for different amounts as well. For example:

    $8\ Ca + 4\ O_2 \rightarrow 8\ CaO$
    $1000\ Ca + 500\ O_2 \rightarrow 1000\ CaO$
    $2\ (6.02 \times 10^{23}\ \text{molecules})\ Ca + 6.02 \times 10^{23}\ \text{molecules}\ O_2 \rightarrow 2\ (6.02 \times 10^{23}\ \text{molecules})\ CaO$

- As you can see, these substances combine in a very specific ratio (in this case 2:1:2)
- This ratio is called the mole ratio (or molar ratio)
  2 moles of Ca combine with 1 mole of O_2 to produce 2 moles of CaO

- But, we do not need exactly 2 moles of Ca and 1 mole of oxygen gas. If we have 1 mole of Ca, we only need 0.5 moles of O_2.
- Ex:
  - $3\ mol\ Ca + 1.5\ mol\ O_2 \rightarrow 3\ mol\ CaO$
  - $0.5\ mol\ Ca + 0.25\ mol\ O_2 \rightarrow 0.5\ mol\ CaO$
  - $0.1\ mol\ Ca + 0.05\ mol\ O_2 \rightarrow 0.1\ mol\ CaO$

- We can use this knowledge to determine how much reactant we need.
  - Ex: We want to produce 0.3 mol of CaO. How much Ca and O_2 is required?
  - Answer:
    - We know the molar ratio is: 2 : 1 : 2
    - We know how much product (CaO) we want: 0.3 mol
    - We also know the amount of Ca must equal the amount of CaO because the molar ratio of these two things is 2:2 (Therefore we need 0.3 mol of Ca)
    - Finally, we know the amount of O_2 must be ½ of the amount of Ca, because the molar ratio is 2:1 (Therefore we need 0.15 mol of O_2)

- Likewise, we can also predict the amount of product.
  - Ex: How much CaO will be produced by 0.175 mol of O_2?
  - Answer:
    - Molar ratio: 2 : 1 : 2
    - CaO is double the amount of O_2, therefore: 2 (0.175 mol) = 0.35 mol of CaO

- The study of chemical reactions is called Stoichiometry.
  - This involves measuring and calculating the amount of elements and compounds involved in a chemical change.
- The molar ratio gives us the building blocks of matter. This is the KEY to all Stoichiometry calculations.

Limiting Reactant

- There are times when there is too much of one substance and not enough of another in order for all the matter available to react.
- The species that does not have enough to completely react all of the other matter is called the limiting reactant.
- The other species is called in excess.
- Example: If we have 5 atoms of Ca and 1 molecule of O_2, what will react?
- Answer:
    - Molar ratio: 2 : 1 : 2
    - Here we can use 2 atoms of Ca for every 1 molecule of O_2. Since we only have 1 molecule of O_2 available, there will be 3 leftover atoms of Ca.
    - Here O_2 is the limiting reactant. Ca is in excess.

Steps to Calculating reactants and products

1) Write a balanced equation
2) Determine the molar ratio of reactants and products
3) Determine what is given and what is required
4) Convert moles to grams and grams to moles depending upon what is given
5) Calculate the unknown using the molar ratio

Example: Calculate the number of moles of sodium oxide that will be produced when 5.0 moles of sodium react with oxygen. (For this question we only use steps 1-3)

Mole-Mass Calculations

- In these types of questions, moles are given and mass is required
- Use the above steps to solve these problems
    - **REMEMBER: the only way we can compare amounts using the balanced formula is to convert everything into moles.**

Example: How many moles of Na are needed to react with oxygen to produce 800.0 g of Na_2O?

Mass-Mass Calculations

- In these types of questions we are given mass and asked to find mass.
- These types of questions are similar to mole-mass questions.
- Once again, remember that the only way we can compare between two different species is to get a balanced equation and compare the amount of MOLES for each. (The molar ratio only works when we use moles of the substances involved.)

Example: Calculate the mass of lithium oxide produced when 100.0 g of lithium reacts with an excess of oxygen.

Actual Yield and % Yield

- In lab conditions, not every single atom reacts (like it should in theory)
- A reactant is added in excess which will cause the limiting reactant to be completely converted into product (all of it is used up).
- The theoretical yield is the yield of the limiting reactant if ALL of it is converted into product. (This does not often happen in reality.)
    - Experimental conditions produce a yield less than the theoretical yield, which is called the actual yield
- To determine the percent yield we use this formula: $$\% \text{ Yield} = \frac{\text{actual yield}}{\text{Theoretical yield}} \times 100$$
- % Yield gives us the efficiency of the reaction (high % is efficient)
- When using solutions, volume and concentrations must be converted into moles to determine yield