Amount of reactants and products problems

$$aA \longrightarrow bB$$

In this type of problems, you are given the mass (#moles) of the reactant and you calculate the mass (#moles) of the product.

You can use the following formula to calculate the #moles of B:

$$\text{number of moles of (B)} = \text{number of moles of (A)} \text{x} \left(\frac{b}{a}\right)$$

You can use the following formula to calculate the mass of B:

$$\text{mass of (B)} = \left(\frac{\text{mass of (A)}}{\text{Molar mass of (A)}}\right) \text{x} \left(\frac{b}{a}\right) \text{x Molar mass of (B)}$$

How many grams of water are produced when 7.00 grams of oxygen react with an excess of hydrogen according to the reaction shown below?

$2H_2(g) + O_2(g)$ ----> $2H_2O(g)$

✓The "excess" reactant has nothing to do with the problem.

✓Identify which is the "given" and which is the unknown.

$2H_2(g) + O_2(g)$ ----> $2H_2O(g)$

10 g ?

Limiting Reagents

$$aA + bB \longrightarrow dD$$

When two substances A and B are present in random quantities and react with each other to produce D, the first consumed one is *the limiting reagent* and the second one is remained in *excess*.

The amount of product should be calculated from the amount of the limiting reactant

To determine the limiting reagent from given moles of substance, do the followings:

1- Calculate the ratio for each reagent, by dividing the given moles of a reagent to its factor in the chemical equation.

2- Compare the ratios for the reagents and the limiting reagent is ***the smallest one***.

If 5 moles of NO were mixed with 5 moles of O_2 to react as: $2NO(g) + O_2(g) \rightarrow 2NO_2(g)$

Determine the limiting reagent.

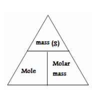
The ratio of $NO = \frac{5\,\text{mol (given)}}{2\,\text{mol (factor)}} = 2.5$

The ratio of $O_2 = \frac{5\,\text{mol}}{1\,\text{mol}} = 5$

The limiting reactant is NO because it is the smallest

If 400g Fe were mixed with 300g O_2 to react as:

$$4Fe(s) + 3O_2(g) \rightarrow 2Fe_2O_3(s)$$



Determine the limiting reagent.

Step 1: Change the mass in grams into moles for the given substances

$400\,\text{g Fe} \times \frac{1\,\text{mol Fe}}{55.8\,\text{g/mole Fe}} = 7.17\,\text{mol Fe}$ $\quad 300\,\text{g}\,O_2 \times \frac{1\,\text{mole}\,O_2}{32\,\text{g/mole}\,O_2} = 9.38\,\text{mol}\,O_2$

Step2: Calculate the ratio and compare

$Fe = \frac{7.17\,\text{mol}}{4\,\text{mol}} = 1.793$ $\quad O_2 = \frac{9.38\,\text{mol}}{3\,\text{mol}} = 3.127$ **Fe is the limiting reactant**

Chemical reaction yield

- **For any chemical reaction there are theoretical and actual (practical) yield.**
- ***Theoretical yield (T.Y.)* is the amount of product that would result if all the limiting reactant reacted.**
- ***Actual yield (A.Y.)* is the amount of product actually obtained from a reaction.**
- **Due to many factors can affected on the reaction, A.Y. is always less than T.Y.**
- ***Percent yield* is the efficient for a given reaction:**

$$\%\ \text{yield} = \frac{A.Y.}{T.Y.} \times 100$$

Many tons of urea ($CO(NH_2)_2$) are produced every year in fertilizer industries. When 119 g ammonia react with 80 g CO2 as the equation: $2NH_3(g) + CO_2(g) \rightarrow CO(NH_2)_2(s) + H_2O$
and produce 100 g urea, calculate % yield?

- Step 1: Determine the limiting reagent

- Change the mass in grams into moles for the given substances

$$119 g\, NH_3 \times \frac{1\, mole\, NH_3}{17\, g\, NH_3} = 7\, mol\, NH_3 \qquad 80 g\, CO_2 \times \frac{1\, mole\, CO_2}{44\, g\, CO_2} = 1.82\, mol\, CO_2$$

- Calculate the ratio and compare

$$NH_3 = \frac{7\, mol}{2\, mol} = 3.5 \qquad CO_2 = \frac{1.82\, mol}{1\, mol} = 1.82$$

CO_2 is the limiting reagent

Now, ignore NH_3 and compare between CO_2 and $CO(NH_2)_2$ only.

- Step 2: Calculate the Theoretical Yield [#moles of $CO(NH_2)_2$]

$$\text{number of moles of (B)} = \text{number of moles of (A)} \times \left(\frac{b}{a}\right)$$

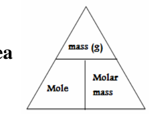
$$\#moles\, CO(NH_2)_2 = \#moles\, of\, CO_2 \times \left(\frac{1}{1}\right) = 1.82\, moles\, CO_2 \times 1$$

Number of moles of $CO(NH_2)_2$ = 1.82 moles

5

Step 3: Calculate the Theoretical Yield [mass of $CO(NH_2)_2$] produces:

The T.Y. $= 1.82\, mole\, urea \times \frac{60 g\, urea}{1 mole\, urea} = 109 g\, urea$



Step 4: Calculate the %Yield of $CO(NH_2)_2$:

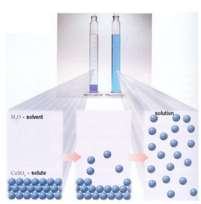
$$\%\, yield = \frac{A.Y.}{T.Y.} \times 100$$

$$\%\, yield = \frac{100}{109} \times 100 = 91.7\,\%$$

6

Solutions and concentration

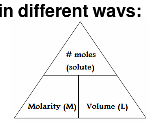
- A solution is a homogeneous mixture of 2 or more substances (gas, liquid, or solid) in a single phase and it contains a solute (the substance that is dissolved in a solvent) and a solvent (a liquid in which a substance is dissolved).
- When the solvent is water, the solution is said to be aqueous (aq).



Concentration of solution can be expressed in different ways:

$$Molarity\,(M) = \frac{\text{moles of solute}}{\text{volume of solution (liter)}}$$

$$Weight\,\% = \frac{\text{weight of solute}}{\text{weight of solution}} \times 100$$

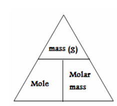


7

Calculate the mass required to prepare a 250 mL 0.01 M solution of $KMnO_4$?

Convert 250 ml to L (250/1000 = 0.250 L)
Using the formula:
\# moles = molarity x volume
= 0.01 mol/L x 0.250 L
=0.0025 mol

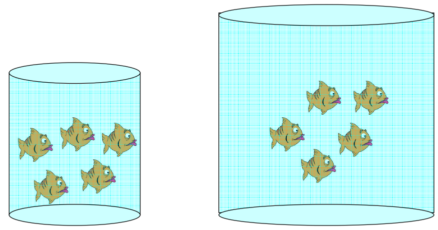
Mass = # moles x molar mass
Molar mass of KMnO4 = 158.0 g/mole
Mass of $KMnO_4$ needed = 0.0025 mol x 158.0 g/mole
= 0.395 g of $KMnO_4$
So, weigh 0.395 g of $KMnO_4$ and dissolve them in 250 ml volumetric flask.



If a solution contains 0.035 moles solute in 2.0 L of water, what is the molarity?
Molarity (M) = moles of solute / volume of solution (liter)
= 0.035 moles / 2.0 L = 1.8 x 10^{-2} M

8

Dilution of concentrated solutions



# fish = 5
Volume = 1 L
Concentration = 5 fishes/1 L

# fish = 5
Volume = 2 L
Concentration = 5 fishes/2 L

- If you have 5 fishes in a 1 L tank and you moved them in another 2 L tank, what will happened?
- The number of the fishes remain the same (5 fishes), but their concentrations changes.
- The fishes are the moles, when you put same number of moles in different volumes, the number of moles stay the same, but the concentrations changed.

Dilution of concentrated solutions

- **When we dilute a solution by mixing it with more solvent, the amount of solute present does not change, but the total volume and the concentration of the solution do change.**
- **To calculate the molarity after dilution, we can use the following formula:**

 # moles before dilution = # moles after dilution

(Molarity x Volume)$_{\text{before dilution}}$ = (Molarity x Volume)$_{\text{after dilutio}}$

$M_1 \times V_1 = M_2 \times V_2$

How many milliliters of 18.0 M H_2SO_4 are required to prepare 1.00 L of a 0.900 M solution of H_2SO_4?

Using the formula: $M_1 \times V_1 = M_2 \times V_2$

M_1 = 18.0 M, V_1=?? And M_2 = 0.900 M, V_2 = 1.00 L

So,
$$V_1 = \frac{M_2 \times V_2}{M_1} = \frac{0.900\,\text{M} \times 1.00\,\text{L}}{18.0\,\text{M}} = 0.0500\text{L} = 50.0\text{mL}$$

mass of reactant or volume of solution of reactant $\xleftrightarrow{\text{molar mass}}$ moles of reactant $\xleftrightarrow{\text{chemical equation}}$ moles of product $\xleftrightarrow{\text{molar mass}}$ mass of product or volume of solution of product

What volume of 1.5 M HCl is required to react with 34.6 mL of 2.44 M NaOH?

$NaOH_{(aq)} + HCl_{(ag)} \rightarrow NaCl_{(aq)} + H2O_{(l)}$

First calculate the number of moles of NaOH:

2.44 M X (34.6/1000)L = 0.0844 mole NaOH

From the chemical equation:

$NaOH_{(aq)} + HCl_{(ag)} \rightarrow NaCl_{(aq)} + H2O_{(l)}$

One mole of HCl reacts with **one mole** of NaOH
0.0844 mole HCl reacts with 0.0844 mole NaOH

Number of moles of HCl = molarity of HCl X volume of solution
0.0844moles HCl = 1.5 M X V
The volume of HCl= 0.056 L = 56 mL

According to the reaction:

$Ba(OH)_{2\,(aq)} + 2\,HNO_{3\,(aq)} \rightarrow Ba(NO_3)_{2\,(aq)} + 2\,H_2O_{(l)}$

What volume of 0.5M HNO_3 is required to react with 41.77 mL of 0.1603 M $Ba(OH)_2$?

From the chemical equation:

$Ba(OH)_{2\,(aq)} + 2\,HNO_{3\,(aq)} \rightarrow Ba(NO_3)_{2\,(aq)} + 2\,H_2O_{(l)}$

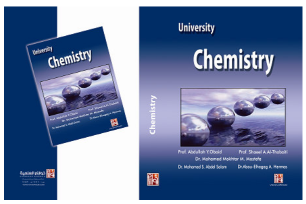
2 Moles of HNO_3 react with **one mole** of $Ba(OH)_2$

moles of $Ba(OH)_2$ = molarity X volume of solution
= 0.1603 M X (41.77/1000) L = 6.696 x 10^{-3} mol

The moles of HNO_3 which reacted = 2 x 6.696 x 10^{-3} = 13.39 x 10^{-3} mol

moles of HNO_3 = molarity X volume of solution
13.39 x 10^{-3} mol = 0.5 M X V
V= 0.0417 L = 41.7 mL

لمزيد من التمارين و الشرح
أحصل على نسختك من كتاب
University Chemistry
من مكتبة خوارزم



13