Objectives

At the end of this unit , the student should be able to :

1- Express amounts of substance in weight units of μg ,mg , g or kg and convert them to moles, or millimoles .

2- Express quantitative relationship using chemical reaction equations; evaluate quantities of reactants and products in a chemical reaction; and solve reaction stoichiometry problems .

3- Define and determine excess and limiting reactants in a reaction mixture; and determine quantities produced in a chemical reaction .

4-Define and determine percentage yield .

5- Understand , chemical equilibrium concept .

6- Understand the factors affecting the equilibrium (Le Chatelier rule) .

7- Calculate the concentrations of reactants and products at equilibrium .

8- Solve any problem concerning stoichiometry and chemical equilibrium .

Introduction

Stoichiometry and equilibrium are the main core of analytical chemistry basics . The student must have a full knowledge of these concepts to be able to have a career in analytical chemistry . Without good understanding of stoichiometry and equilibrium , student may have difficulty understanding the rest of this course .

Stoichiometry and equilibrium are very important everywhere. To prepare certain amount of anything you should mix the components in well known proportions , whether in chemical laboratory , in industry and even in kitchen . The capsa is not going to be delicious if you do not mix the appropriate proportions of rice , water and other components .

Stoichiometry

Stoichiometric Relationships in chemical reactions :

For the purpose of clarifying and simplifying the quantitative relationships in a chemical reaction let's discuss the following general example :

$$aA + bB \leftrightarrow eE + dD$$

To find the amount (moles or mmoles) of any reactant or product participating in a chemical reaction based on the amount of an another reactant or product participating in the same reaction we follow the following three important steps :

Stoichiometry (gams to moles)

Step 1 :

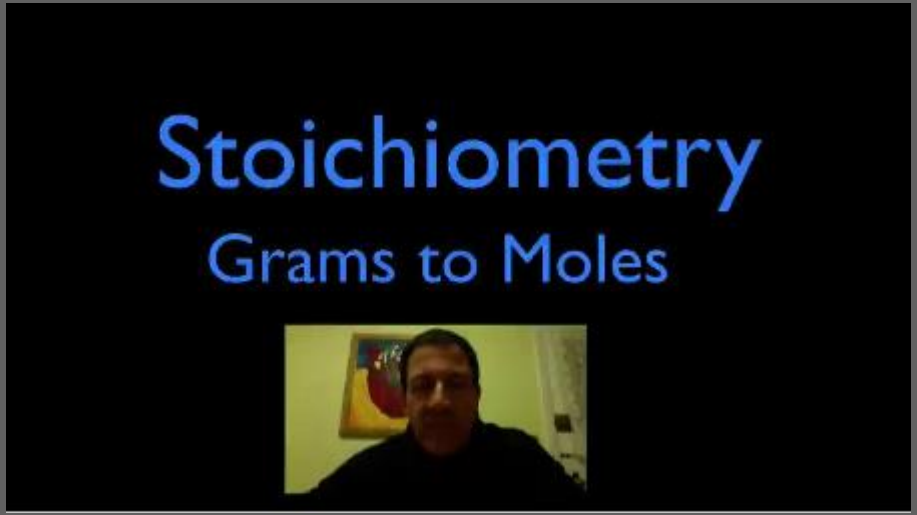
conversion of the question data [e.g weights in g or mg , volume of solution in liter (V_L) or milliliter (V_{mL}) , molarity (M)] of a reactant and/or a product in to moles or mmloes thus :

$$\frac{weight\,(g)}{mw} = moles$$

$$V_L \; X \; M = moles$$

$$\frac{weight\,(mg)}{mw} = mmoles$$

$$V_{mL} \; X \; M = mmoles$$



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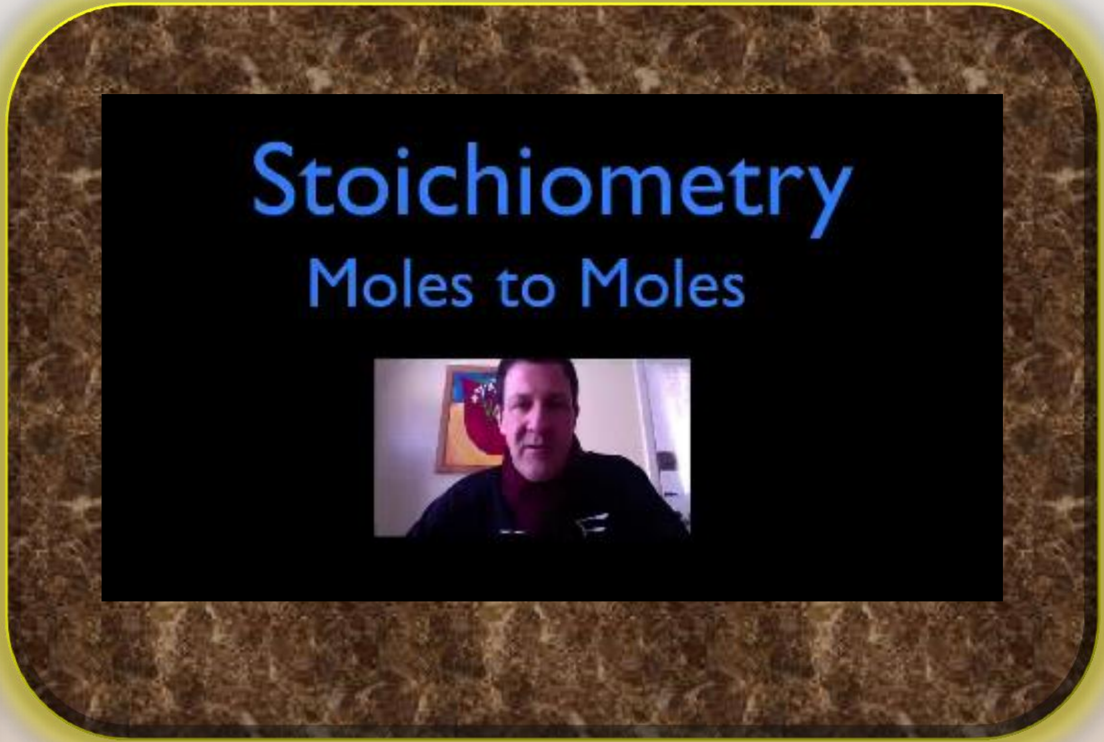
Stoichiometry (moles to moles)

Step 2 :

Using the mole ratio of the balanced chemical reaction equation we can calculate the number of moles or mmoles of the unknown reactants and/or procucts from the known moles or mmoles of another reactant and/or product participating in the same reaction thus :

$$\frac{\text{reacted mol } A}{a} = \frac{\text{reacted mol } B}{b} = \frac{\text{produced mol } E}{e} = \frac{\text{produced mol } D}{d}$$



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Stoichiometry (moles to moles)

The capital letters (A , B , E and D) indicate the real amounts of these substances (moles or mmoles) reacted or produced while the small letters represents the number of moles or mmoles of each substance reacted or produced according to the above balanced chemical equation .From the last formula we can write the following equations :

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Stoichiometry (moles to moles)

$$\text{reacted moles } A = \text{reacted moles } B \text{ X } a/b$$
$$= \text{produced moles } E \text{ X } a/e$$
$$= \text{produced moles } D \text{ X } a/d$$

$$\text{reacted moles } B = \text{reacted moles } A \text{ X } b/a$$
$$= \text{produced moles } E \text{ X } b/e$$
$$= \text{produced moles } D \text{ X } b/d$$

$$\text{produced moles } E = \text{reacted moles } A \text{ X } e/a$$
$$= \text{reacted moles } B \text{ X } e/b$$
$$= \text{produced moles } D \text{ X } e/d$$

$$\text{produced moles } D = \text{reacted moles } A \text{ X } d/a$$
$$= \text{reacted moles } B \text{ X } d/b$$
$$= \text{produced moles } E \text{ X } d/e$$

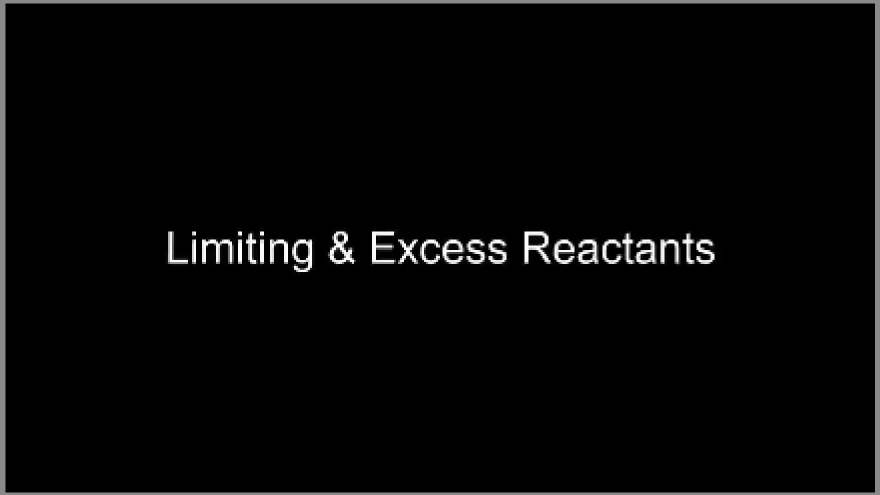
Stoichiometry (moles to moles)

Notes :

1- we use either only moles or only mmoles for all reactants and products .

2- Excess reactant is the reactant that some of its amount remains after the reaction is completed .

3- limiting reactant is the reactant that totally converted to products i.e non of its amount were remained after the reaction is completed .



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Stoichiometry (moles to grams)

Step 3 :

Conversion of the calculated unknown moles or mmoles of reactants or products in to grams or milligrams respectively by multiplying by their molecular weight as indicated by the following examples

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VIDEO
Stoichiometry

VIDEO
Stoichiometric Problems

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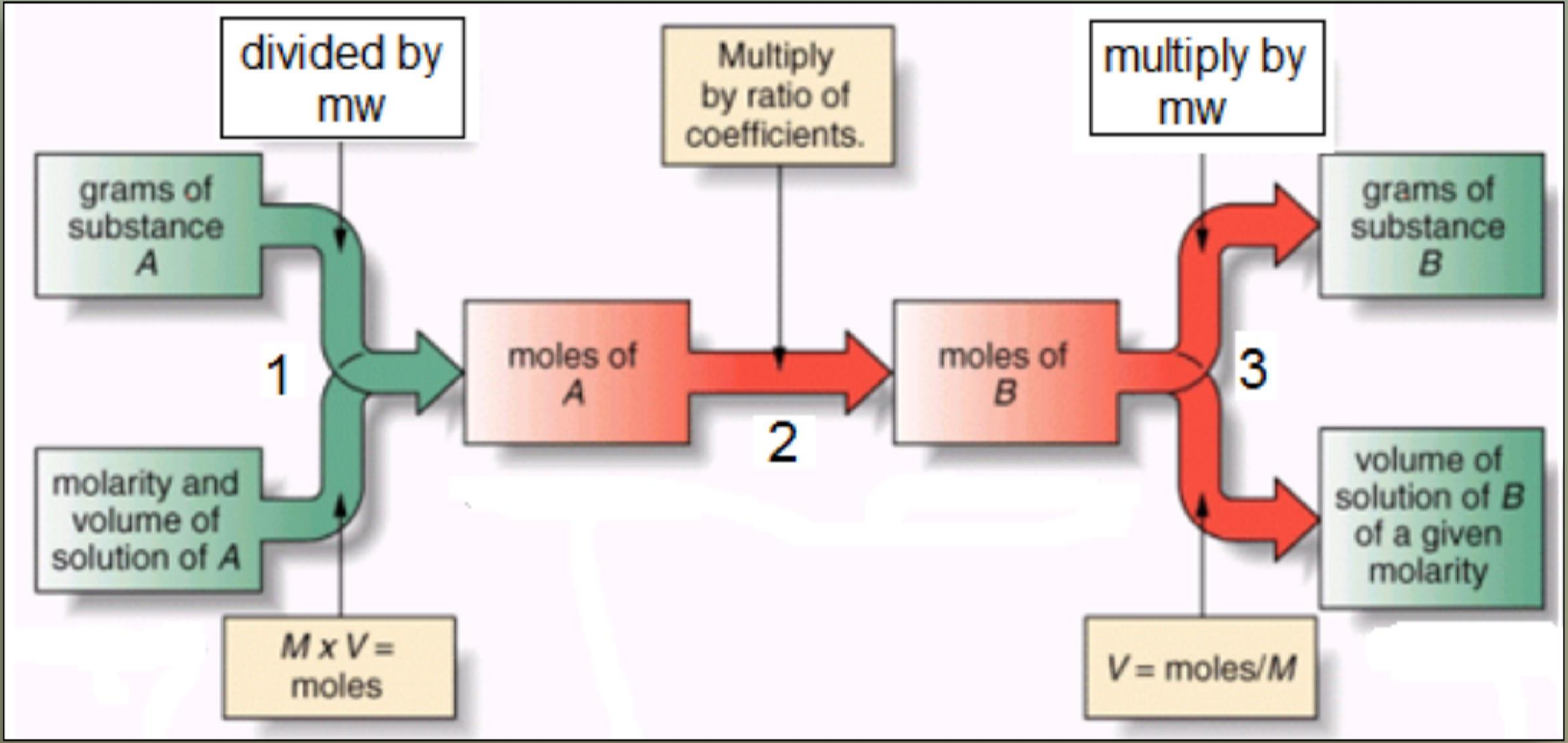
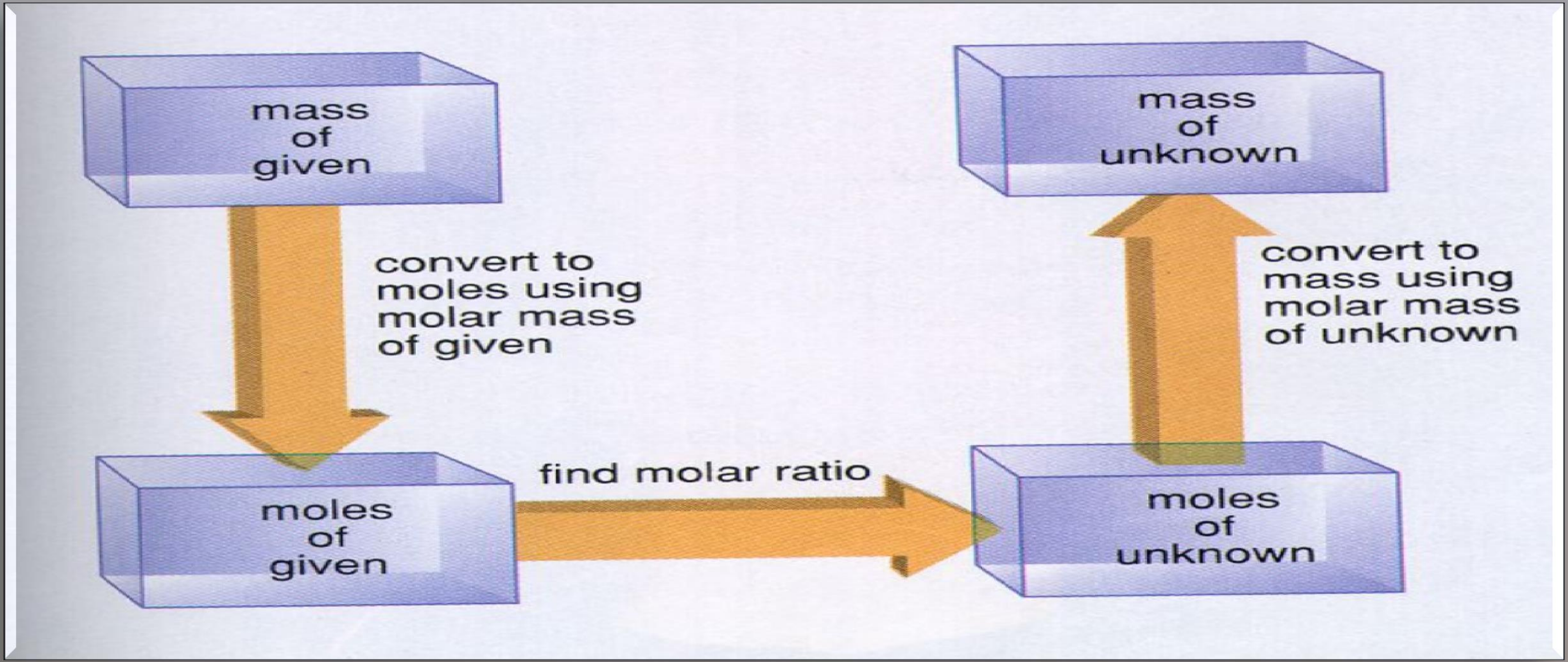
VIDEO
Limiting reactant

Stoichiometry



Stoichiometry



Stoichiometry (Examples)

Example : 5 g of substance A (mw = 100) were added to 50 mL of 0.6 M of substance B and the volume was completed to 500 mL , the following complete reaction has occurred :

$$2A + 3B \rightarrow 4E$$

(1) Identify the limiting reactant ?

(2) Calculate the weight of substance E (mw = 50) produced?

(3) Calculate the molar concentration of the remaining of the excess reactant ?

VIDEO
Stoichiometry

Stoichiometry (Examples)

Solution :

step 1 : (mass $\longrightarrow$ mole) :
question data are converted to only moles or only mmoles thus:

$$mmoles\ \ A = \frac{5\,(g)\ X\ 10^{3}\ (mg)}{100\ (mw)} = 50\, mmoles$$

$$or \quad = \frac{5}{100}\ (moles)\ X\ 10^{3}\ (mmoles) = 50\ mmoles$$

$$mmoles\ \ B = 50\ (mL)\ X\ 0.6\ (M) = 30\ mmoles$$

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Stoichiometry (Examples)

Step 2 : (mole $\longrightarrow$ mole) :

Calculating the moles or mmoles of unkown participating substances from the known moles or mmoles of participating substances according to the balanced chemical reaction equation.

If we calculate the mmoles of B required to react with 50 mmoles of A we will get 75 mmoles of B thus :

mmoles B required to react with 50 mmol A

$= 50 \times 3/2 = 75$ mmol

But there are only 30 mmoles of B so instead we calculate the mmoles of A required to react with 30 mmoles of B thus :

Mmoles A = $30 \times 2/3 = 20$ mmoles

excess mmoles A $= 50 - 20 = 30$

Stoichiometry (Examples)

$$\frac{reacted\ \ mmoles\ \ A}{2} = \frac{reacted\ \ mmoles\ B}{3} = \frac{produced\ \ mmoles\ \ E}{4}$$

$$\frac{20}{2} = \frac{30}{3} = \frac{x}{4}$$

$$produced\ mmoles\ E\,(\,x\,) = 20\ X\,\frac{4}{2} = 30\ X\,\frac{4}{3} = 40\ \ mmoles$$

This can be clarified by the following :

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Stoichiometry

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Stoichiometry (Examples)

		2A	+	3B	$\rightarrow$	4E
I	(mmoles)	50		30		0
C	(mmoles)	30		0		40

Remember ICE :

I means Initial (before reaction)

C means at Complete reaction

E means at Equilibrium .

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Stoichiometry

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Stoichiometry

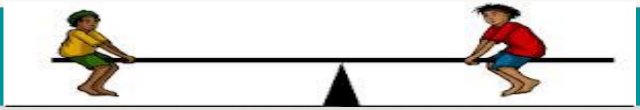
Step 3 : (mole $\longrightarrow$ mass) :

(2) The weight of E = 40 (mmoles) X 50 (mw)
= 2000 mg = 2 g

(3) $$\textit{The molarity of the remaining of } A(M_A) = \frac{30\ mmoles}{500\ mL}$$

$$= 0.06\ M$$

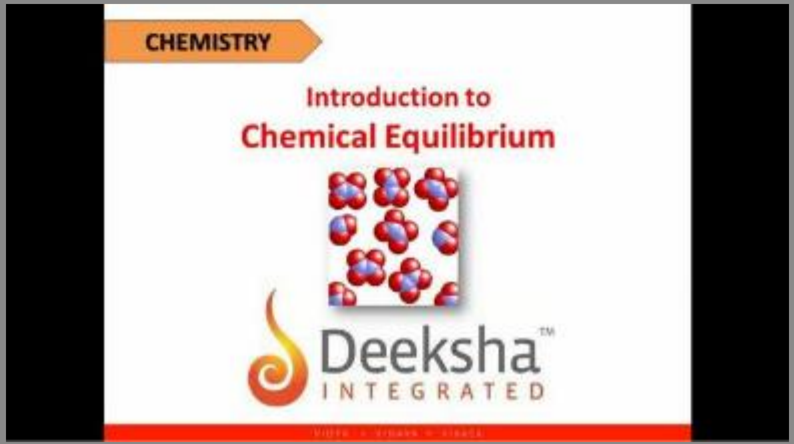
Chemical Equilibrium



Most chemical reactions are not quite 100 % complete , they reach a state in which there are two reactions opposite to each other one called forward (proceed from left to right) and the other called backward (proceed from right to left) . Let us look at the following general reaction equation :

$$aA \quad + \quad bB \quad \overset{R_1}{\underset{R_2}{\rightleftharpoons}} \quad eE \quad + \quad dD$$

Where R_1 and R_2 are the rates of the forward and the backward reactions respectively :



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VIDEO Equilibrium

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Chemical Equilibrium

R_1 direct proportional to $[A]^a\ [B]^b$

$$R_1 = K_1\ [A]^a\ [B]^b$$

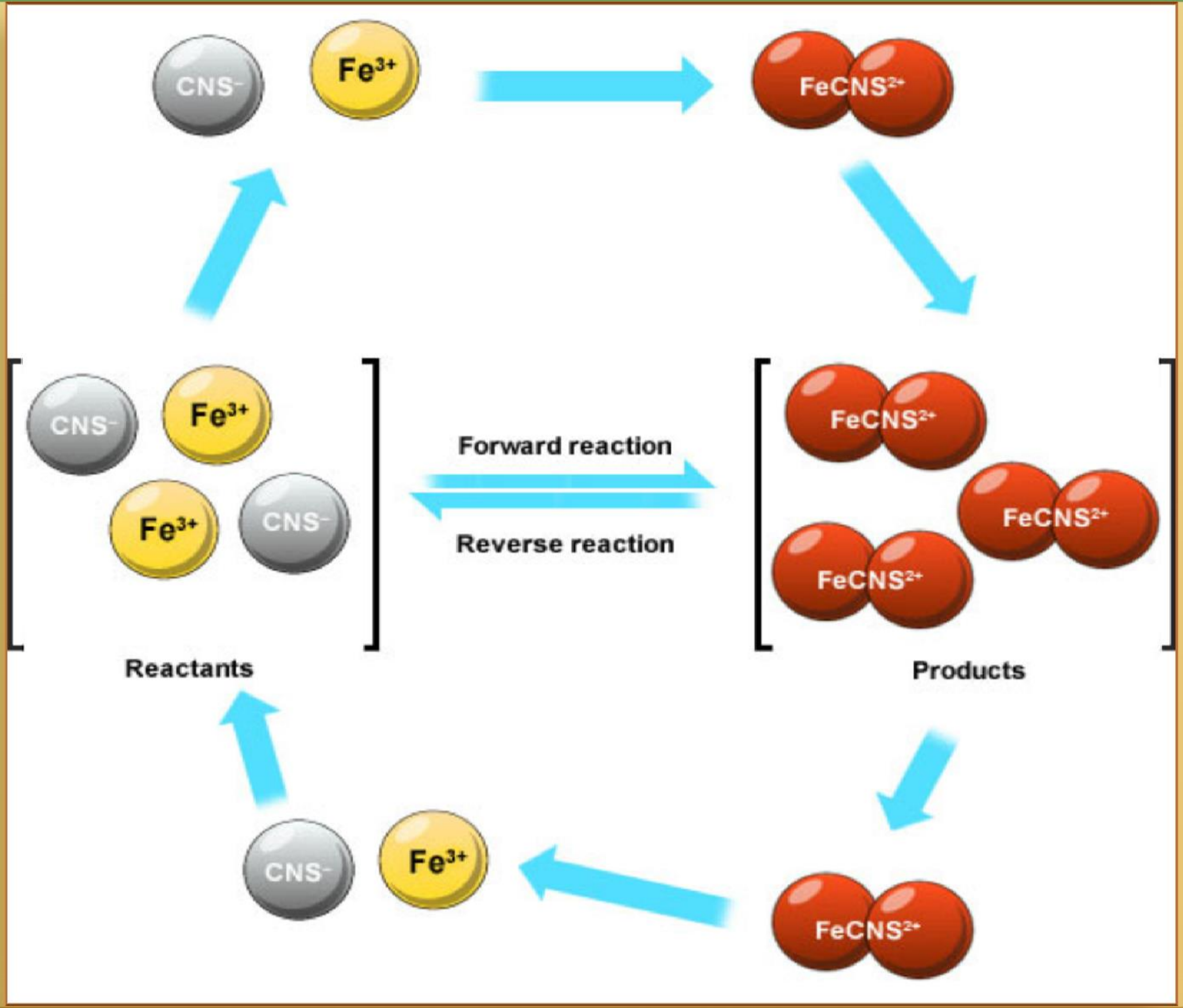
like wise

$$R_2 = K_2\ [E]^e\ [D]^d$$

Where K_1 and K_2 are the rate constants of the forward and the backward reactions respectively and [ ] represent the concentration in M , g/L … etc . Note that $[H_2O] = 1$ and also [solid] = 1

When a chemical reaction reaches an equilibrium

$$R_1 = R_2$$



Chemical Equilibrium

$$K_1 \ [A]^a \ [B]^b \ = \ K_2 \ [E]^e \ [D]^d$$

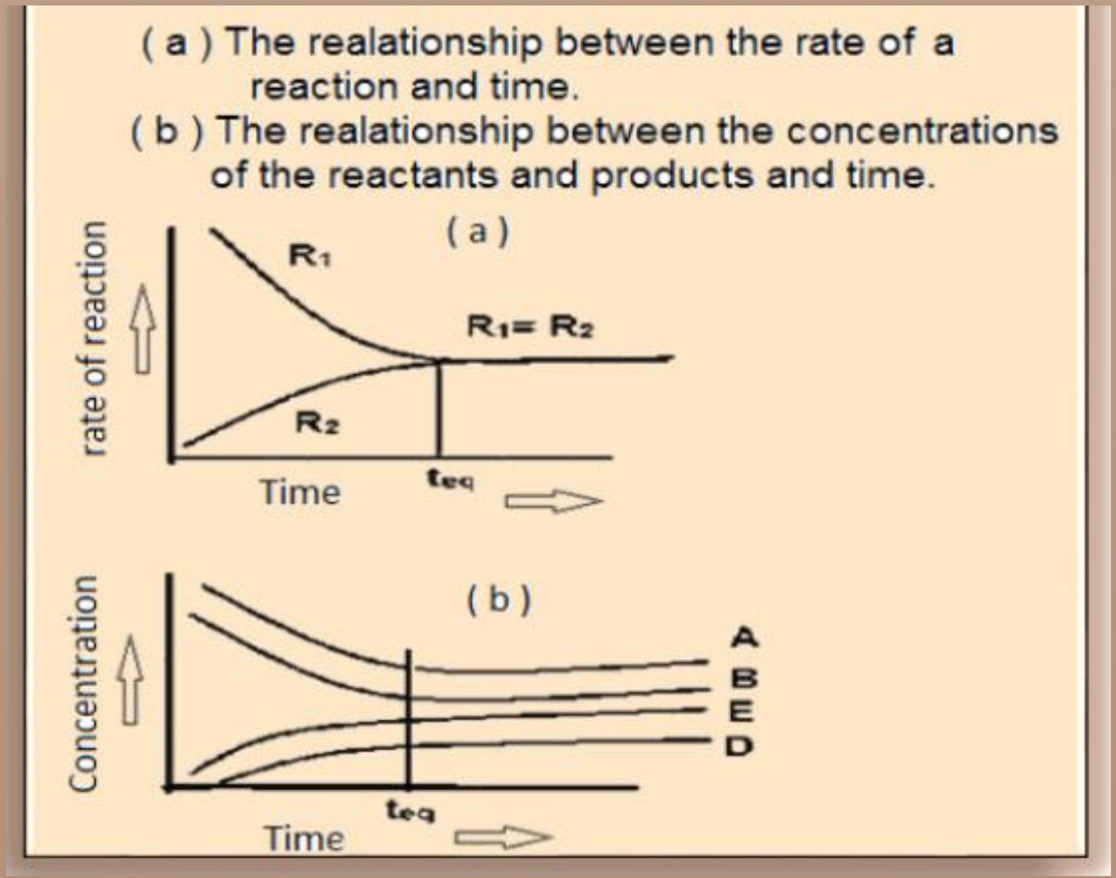
By rearranging the above equation we get the following equilibrium constant equation :

$$K_{eq} = \frac{K_1}{K_2} = \frac{[E]^e[D]^d}{[A]^a[B]^b}$$

The figure on the next slide illustrates the idea of chemical equilibrium where at the start of a reaction $R_1 >> R_2$ and when the reaction proceed R_1 becomes lower while R_2 becomes higher and when the reaction reaches the time of equilibrium (t_{eq}) , R_1 becomes equal to R_2 . Also we note that the concentrations of reactants (A and B) become lower and the concentration of products become higher and at equilibrium all become constant .

Chemical Equilibrium

In other words chemical equilibrium is a state in which the rates of the forward and backward (reverse) reactions are equal and the concentrations of the reactants and products remain constant . Equilibrium is a dynamic process where the conversions of reactants to products and products to reactants are still going on, although there is no net change in the number of reactant and product molecules .



Chemical Equilibrium (general remarks)

General remarks on the equilibrium :

1- The time required for the reaction to reach an equilibrium (t_{eq}) varies from one reaction to an other , some parts of a second and some several days . The reactions applied in analytical chemistry usually reach the equilibrium within several minutes.

2- The value of a chemical equilibrium constant K_{eq} depends on several factors such as the nature of reactants and their ability to react with each othere and temperature …etc but it has nothing to do with the rate of the reaction . Some reactions have a high K_{eq} value and yet they are slow . The value of K_{eq} indicates the completeness of the reaction and varies from less than 1 (reverse reaction) to 10^{100} or more .

3- K_{eq} value predicts the direction of reaction . If the value is very high ($K_{eq} >> 1$) the reaction will go to the right and be more complete but if the value is very small ($K_{eq} << 1$) the reaction will go to the left and be less complete (backward) .

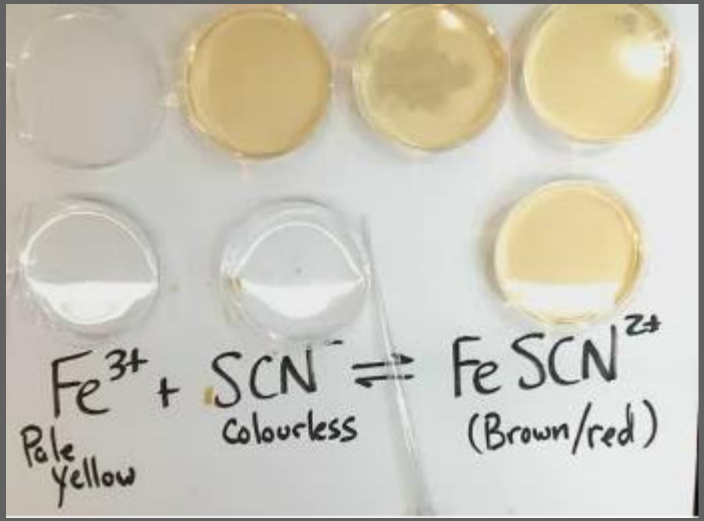
Chemical Equilibrium (Le Chatelier principle)

Factors affecting equilibrium (Le Chatelier principle) :

1-The concentration : The increase in the concentration of one of the reactants (usually the reagent not the analyte) will move the reaction to the right(forward) i.e the products will increase and reactants will decrease (position of equilibrium) so that the reaction will be more complete but the value of the equilibrium constant of the reaction wil not change . Also the reaction can be made more complete by removal of one of the products by volatilization or precipitation or masking .

Chemical Equilibrium (Le Chatelier principle)

In other words Adding a reactant or product, the equilibrium shifts away from the increase in order to consume part of the added substance while removing a reactant or product, the equilibrium shifts toward the decrease to replace part of the removed species .



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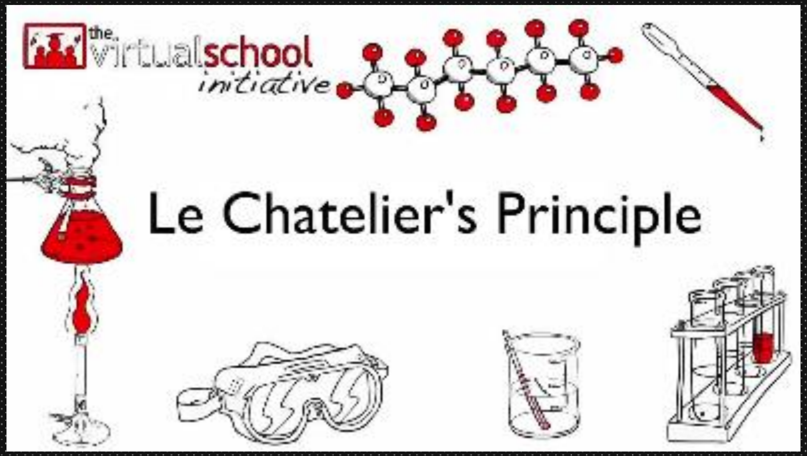
Chemical Equilibrium (Le Chatelier principle)

2- Temperature : Heat can be considered a reactant in an endothermic reaction (reactants + heat $\rightarrow$ products) and a product in an exothermic (reactants $\rightarrow$ products + heat) .

Recall that both K_{eq} and the position of the equilibrium system will vary with temperature :

K_{eq} is larger when the reaction shifts right. This occurs if temperature is increased for an endothermic reaction or decreased for an Exothermic reaction .

K_{eq} is smaller when the reaction shifts left. This occurs if temperature is decreased for an endothermic reaction or increased for an exothermic reaction .



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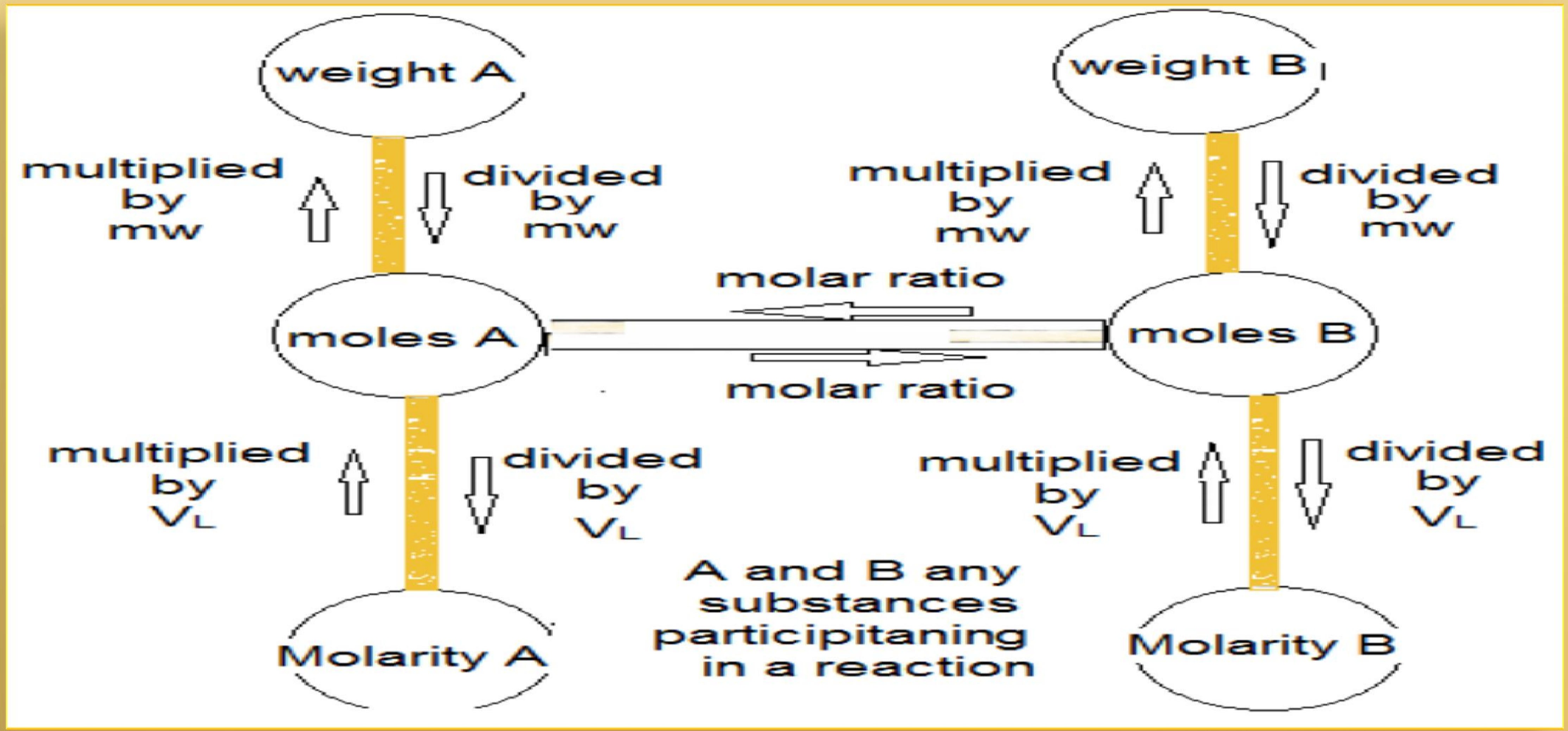
Chemical Equilibrium (Le Chatelier principle)

3- The pressure : The pressure will affect both the value of K_{eq} and the position of the equilibrium (concentrations of reactants and products at equilibrium) if the reaction includes gas either within the reactants (where the increased pressure will increase the value of the equilibrium constant) or within the products (where the increased pressure will reduce the value of K_{eq}) .The effect of the pressure is very little on aqueous solutions

Chemical Equilibrium (Le Chatelier principle)

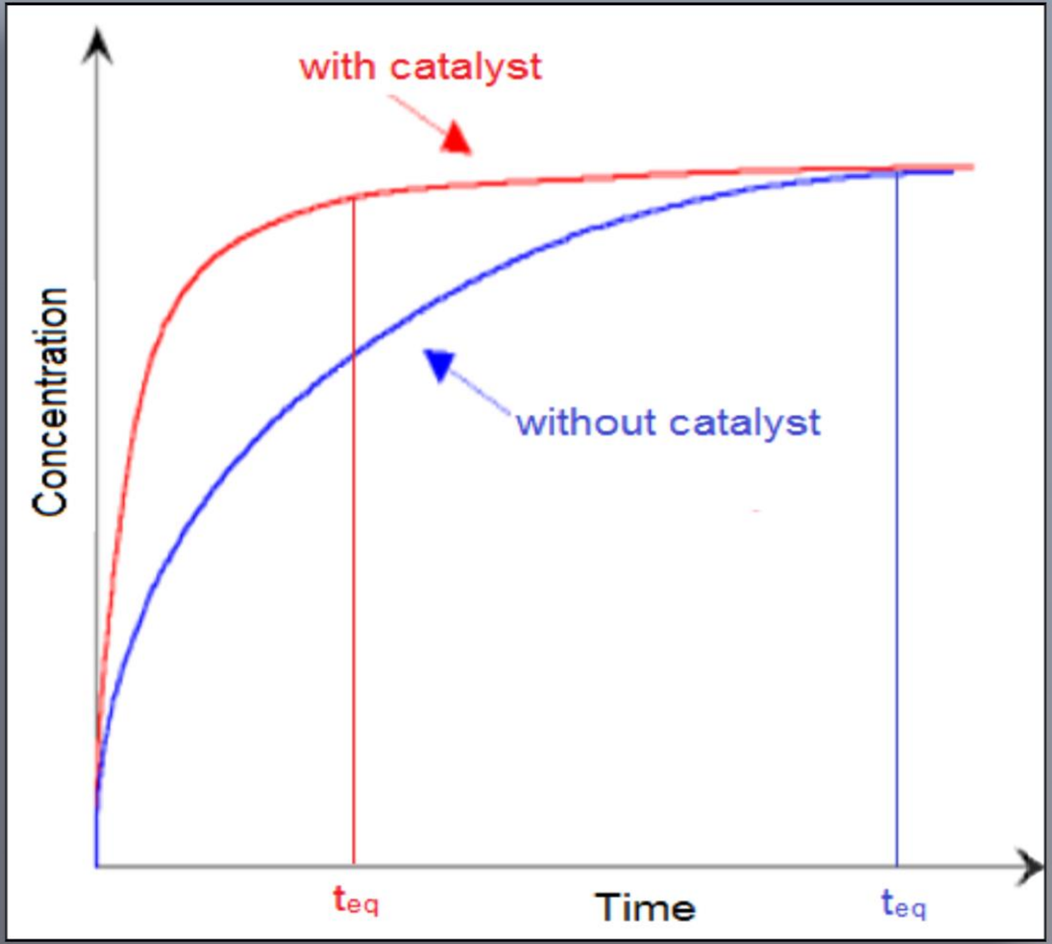


Chemical Equilibrium (Le Chatelier principle)

4- Effect of a Catalyst

a catalyst decreases the amount of time taken to reach equilibrium but it does not affect the equilibrium concentrations of reactants and products in the equilibrium mixture; thus, the K_{eq} value does not change . Most organic reactions are slow and need heat and/or catalysts to speed them up and help in breaking double and triple bonds on the contrary most inorganic ionic interactions are fast .

5- The nature of solvent : The value of K_{eq} depends very much on the nature of the solvent .



Chemical Equilibrium (solving problems)

3.4 Simple method for solving equilibrium promlems : Suppose you have a liter of solution containing 0.1 mole of A and 0.2 mole of B and the reaction between these two substances occurred according to the following equation :

$$A + B \leftrightarrow E + D \qquad K_{eq} = \ldots..$$

The equilibrium problem can be solved in accordance with the value of K_{eq} , thus :

If K_{eq} << 1 : Looking to the K_{eq} equation , this means that the amounts of pruducts are very small and the amounts of reactants are large so we express the products by x which can be neglected :

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VIDEO
Stoichiometric Problems

VIDEO
Quantitative relationships

Chemical Equilibrium (solving problems)

	A	+	B	$\leftrightarrow$	E	+	D
befor reaction (moles/L)	0.1		0.2		0		0
at equilibrium (moles/L)	0.1 - x		0.2-x		x		x

Then we compensate in the K_{eq} equation thus :

$$K_{eq} = \frac{[E][D]}{[A][A]}$$

$$= \frac{[x][x]}{[0.1 - x][0.2 - x]}$$

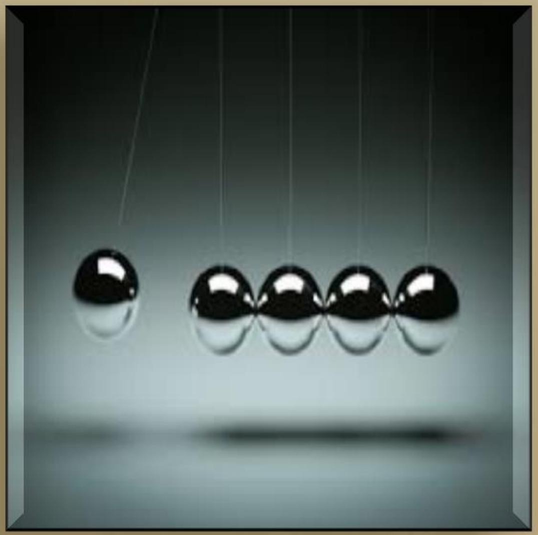
The above equation is either converted into quadratic equation :

$$ax^2 + bx + c = 0$$

which can be solved by the well known following equation :

Chemical Equilibrium (solving problems)

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$



Or we can make the calculations easer by neglecting x (approximation) , thus :

$$K_{eq} \approx \frac{[x][x]}{[0.1][0.2]}$$

Note that x is neglected only if it is subtracted from or added to a number but can not be neglected if it is alone or multiplied by a number . This choice will be applied in this course to make the calculations easer .When we obtain the value of x we can calculate the amount of any product or reactant at equilibrium as we will see later .

Chemical Equilibrium (solving problems)

If K_{eq} >> 1 : This means that the amounts of reactants are very small and the amounts of products are large so we express the reactants by x starting from the limiting reactant . Remember ICE :

	A +	B	↔ E +	D
I (moles/L)	0.1	0.2	0	0
C (moles/L)	0	0.2 – 0.1= 0.1	0.1	0.1
E (moles/L)	x	0.1+x	0.1-x	0.1-x

When the reaction is complete , the amount of remaining A is equal to 0 (it is the limiting reactant) while the amount of remaining B is equal to 0.1 but at equilibrium we assume that the remaining amount of A to be x so the amount of remaining B will be 0.1 + x . The remaining x will be on the expense of the amounts of the products so we subtract x from these amounts. Then we compensate in the K_{eq} equation thus :

$$K_{eq} = \frac{[0.1 - x][0.1 - x]}{[x][0.1 + x]}$$

Chemical Equilibrium (solving problems)

Now we either use the quadratic equation or easily neglect x , thus :

$$K_{eq} = \frac{[0.1][0.1]}{[x][0.1]}$$

In both above cases by calculating x which means moles or mmoles we can calculate the weight and/or the concentration of any reactant or product as will be shown in the coming examples .

Chemical Equilibrium (percent yield)

In chemistry , the reaction yield is the amount of product produced by a chemical reaction . The theoretical yield is the maximum amount of product that can be produced in a perfectly efficient reaction . In reality, most reactions are not perfectly efficient - the reaction's actual yield is usually less than the theoretical yield. To express the efficiency of a reaction, calculate the percent yield using this formula :

%yield = (actual yield / theoretical yield) x 100

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Percent Yield

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Examples on Equilibrium and Stoichiometry

Example : For the balanced equation shown below , if the reaction of 35.5 g of ZnS (mw = 97.4) produces 17.3 g of SO_2 (mw = 64.1) , what is the percent yield ?

$$2ZnS + 3O_2 \rightarrow 2ZnO + 2\,SO_2$$

Solution :

Theoretical yield = (35.5 / 97.4) X 64.1 = 23.4 g

Actual yield = 17.3 g

% yield = (17.3 / 23.4) X 100 = 73.9 %

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Examples on Equilibrium and Stoichiometry

Example : 5 g of B (mw= 50) have been added into 100 mL of 1.0 M of A . The volume has been completed to 500 mL . The following reaction was occurred :

$$A + 2B \leftrightarrow 3D$$

Calculate :

(1) The weight of D (mw = 100) and the molar concentration of the remaining B at equilibrium when $K_{eq} = 1 \times 10^{10}$?

(2) The weight of D (mw = 100) and the molar concentration of the remaining B at equilibrium when $K_{eq} = 1 \times 10^{-3}$?

Examples on Equilibrium and Stoichiometry

Solution :

(1) $K_{eq} >> 1$ therefore we will treated as mentioned above using the approximation :

	A	+	2B	$\leftrightarrow$	3D
I (mmoles)	100x1.0= 100		5/50 =0.1 mole=100 mmoles		0
C (mmoles)	100 – 50 = 50		0		150
E(mmoles)	50 + x		2x		150-3x

$$K_{eq} = \frac{[150-3x]^3}{[50+x][2x]^2} = 1\,X\,10^{10} \quad \therefore\ x \approx 1.1\,X\,10^{-4}$$

Examples on Equilibrium and Stoichiometry

$$[B] = \frac{no.\ mmoles}{Vol.(mL)} = \frac{2x}{500} = \frac{2\ X\ 1.1\ X\ 10^{-4}}{500} = 4.4\ X\ 10^{-7}\ M$$

Weight of D = mmoles D X mw_D

$= (\ 150 - 3x\ )\ mw_D$

$= (\ 150 - 3\ X\ 1.1X10^{-4}\ )\ \ X\ 100 = 14999.97$ mg

We can calculate the weight and the concentration of any substance participated in the reaction by the same way .

Examples on Equilibrium and Stoichiometry

(2) $K_{eq} << 1$ therefore we will deal with it as mentioned above using the approximation :

	A	+	2B	$\leftrightarrow$	3D
I (mmoles)	100X1.0 =100		mmoles (5/50 mole X 10^3)= 100		0
E (mmoles)	100- X		100 –2x		3X

Note that here we do not need the complete stage .

$$K_{eq} = \frac{[3x]^3}{[100 - x][100 - 2x]^2} = 1X10^{-3}$$

$$\therefore \quad x \approx 37 \; mmoles$$

Examples on Equilibrium and Stoichiometry

$$[B] = \frac{no.\ mmoles}{Vol.\ (mL)} = \frac{(100-2x)}{500} = \frac{100 \ - 2\ X\ 37}{500} = 0.052\ M$$

weight of D = (3x) X mw_D =(3 X 37) X 100 = 11100 mg

What do you conclude from comparing the results of (1) and (2)?

Example :

Calculate the molar concentration of [H^+] in 0.16 M solution of dichloroacetic acid $Cl_2CHCOOH$ ($K_a = 5 \text{ X } 10^{-3}$) . The concentration of the acid is initial (before dissociation) ?

Examples on Equilibrium and Stoichiometry

Solution :

		$Cl_2CHCOOH$	$\leftrightarrow$	Cl_2CHCOO^-	+	H^+
I	(moles/L)	0.16		0		0
E	(moles/L)	0.16 – x		x		x

$$K_a = \frac{[x][x]}{[0.16-x]} \approx \frac{x^2}{0.16} \approx 5\ X10^{-3}$$

$$x = 0.0283\ M = [H^+]$$

Example : 1.93 g of HNO_2 (mw = 47) were dissolved in water and the volume was completed to 500 mL with water . If the concentration of H^+ in this solution is 7.63 $X10^{-3}$ M , calculate the dissociatin constant of the acid K_a ?

Examples on Equilibrium and Stoichiometry

Solution : First we calculate the molar concentration of the acid (mass $\rightarrow$ mole) :

$$[HNO_2] = \frac{no.mmoles}{V_{mL}} = \frac{\dfrac{Wt._{HNO_2}(mg)}{mw_{HNO_2}}}{500\ (mL)}$$

$$= \frac{\dfrac{1.93(g)\ X\ 10^3\ (mg)}{47}}{500\,(mL)} = 0.08\ M$$

Then we look to the reaction equation :

Examples on Equilibrium and Stoichiometry

	HNO_2	$\leftrightarrow$	H^+	+	NO_2^-
I (moles/L)	0.08		0		0
E (moles/L)	$0.08 - 7.63X10^{-3}$		$7.63X10^{-3}$		$7.63X10^{-3}$

subsequently , we calculate K_a by substitution in the dissociation constant equation :

$$K_a = \frac{[H^+][NO_2^-]}{[HNO_2] - [H^+]}$$

$$= \frac{[7.63X10^{-3}][7.63X10^{-3}]}{0.08 - 7.63X10^{-3}}$$

$$= 8.0\ X\ 10^{-4}$$

Examples on Equilibrium and Stoichiometry

The equilibrium constants that we will discuss in this course are : the dissociation of an acid (K_a) , the dissociation of a base (K_b) , the solubility product (K_{sp}) , the formation constant (K_f) of a complex and the dissociation constant (K_d) of a complex .

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Le Chatelier's Principle

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Summary

The definition of stoichiometry and equilibrium have been addressed . Calculations of the amounts of reactant and/or products whether at equilibrium or at complete reactions are investigated in some details . The factors affecting both the position of the equilibrium and the value of K_{eq} (Le Chatelier principle) are well discussed . the student should be aware of terms such as limiting reactant , excess reactant and percent yield. This unit is supported by so many solved examples , exercises , quizzes and homework .

Tutorial

Exercise 1 : Calculate the weight of the formed $La(IO_3)_2$ [mw=663.6] precipitate after mixing 50 mL solution of 0.2 M of La^{3+} with 75 mL solution of 0.2 M of IO_3^- ?

$$La^{3+} + 3\ IO_3^- \rightarrow La(IO_3)_3$$

Your answer :

Our answer next slide

Tutorial

Answer 1 : We suppose the reaction is complete because K_{eq} is not given

	La^{3+}	+	$3\ IO_3^-$	$\leftrightarrow$	$La(IO_3)_3$
before reaction (mmoles)	50 x 0.2 = 10		75 x 0.2 = 15		0
at complete reaction (mmoles)	5		0		5

$$\text{Wt. of } La(IO_3)_3 = 5 \times 663.6 = 3318 \text{ mg}$$

Tutorial

Exercise 2 : Calculate the weight of SO_2 (mw = 64) that formed when 19 g of CS_2 (mw = 76) was burned according to the following complete reaction :

$$CS_2 + 3O_2 \rightarrow CO_2 + 2SO_2$$

Your answer :

Our answer next slide

Tutorial

Answer 2 :

	CS_2	+	$3\ O_2$	$\rightarrow$	CO_2	$+\ 2\ SO_2$
before combustion (mole)	19/ 76 = 0.25		excess		0	0
after combustion (mole)	0		excess		0.25	0.50

$$\text{Wt. } SO_2 = 0.50 \text{ X } 64 = 32 \text{ g}$$

Tutorial

Exercise 3 : Calculate the weight of $PbCl_2$ (mw = 288) which is formed As a result of mixing 100 ml 0.15 M of Pb^{+2} with 200 ml 0.25 M of Cl^- according to the following complete reaction :

$$2Cl^- + Pb^{+2} \rightarrow PbCl_2$$

Your answer :

Our answer next slide

Tutorial

Answer 3 : ICE means I symbolize for **I**nitial i.e. before reaction , **C** symbolize for at **C**omplete reaction and **E** symbolize for at Equilibrium

	$2\,Cl^-$	+	Pb^{2+}	$\rightarrow$	$PbCl_2$
(I) (mmoles)	200 x 0.25 = 50		100 X 0.15 = 15		0
(C) (mmoles)	50 – 30 = 20		0		15

Wt. $PbCl_2$ = 15 X 288 = 4320 mg

Tutorial

Exercise 4 : Calculate the weight of SO_2 (mw = 64) that formed when 19 g of CS_2 (mw = 76) was burned according to the following complete reaction :

$$CS_2 + 3O_2 \rightarrow CO_2 + 2SO_2$$

Your answer :

Our answer next slide

Tutorial

Answer 4 :

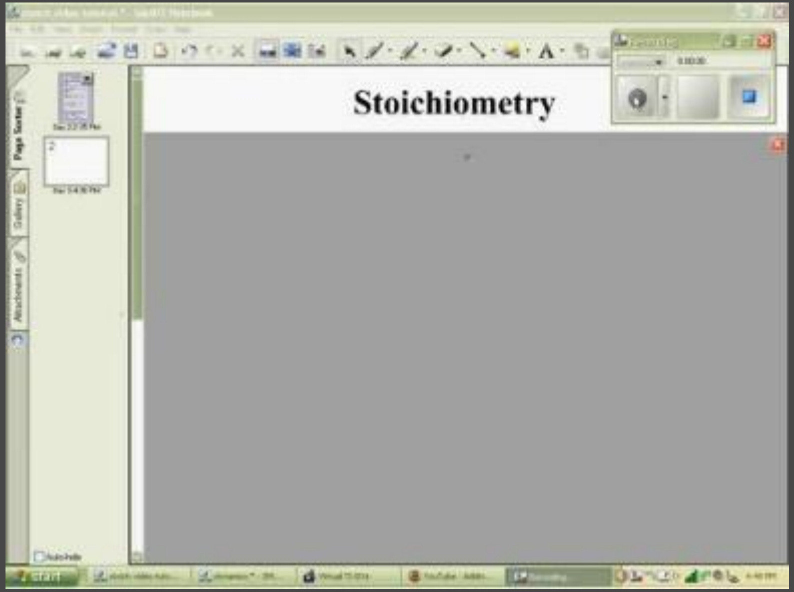
	CS_2	+	$3\ O_2$	$\rightarrow$	CO_2	$+\ 2\ SO_2$
before combustion (mole)	19/ 76 = 0.25		excess		0	0
after combustion (mole)	0		excess		0.25	0.50

$$\text{Wt. } SO_2 = 0.50 \times 64 = 32 \text{ g}$$

STOICHIOMETRY AND EQUILIBRIUM

Tutorial

This video simplify the concept of stoichiometry .



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Tutorial

Exercise 5 : 10 g of the compound BA (mw = 100) are dissolved in water . The volume is completed to 500 mL with water . The following dissociation reaction is occurred :

$$BA \leftrightarrow B + A \quad , \quad K_{eq} = 1X10^5$$

Calculate the molar concentration of A in this solution at equilibrium ?

Your answer :

Our answer next slide

Tutorial

Answer 5 :

	BA	$\leftrightarrow$	B	+	A	, $K_{eq} = 1 \times 10^5$
(I) (moles)	10/100 = 0.1		0		0	
(C) (moles)	0		0.1		0.1	
(E) (moles)	x		(0.1 – x)		(0.1 – x)	

$$K_{eq} = 1x10^5 = \frac{(0.1-x)(0.1-x)}{x} \approx \frac{(0.1)(0.1)}{x}$$

$$x \approx 1x10^{-7} \ mole$$

$$[A] = \frac{[0.1-(1X10^{-7})]\, moles}{500X10^{-3}(L)} \approx 0.2\ M$$

Tutorial

Exercise 6 : Calculate the volume of 2.0 M solution of solute A that should be added to an excess amount of reactant B in order to produce 5 g of A_2B precipitate (mw = 20) according to the following complete reaction :

$$2\,A + B \rightarrow A_2B$$

Your answer :

Our answer next slide

Tutorial

Answer 6 :

	$2A$	+	B	$\rightarrow$	A_2B
(I) (moles)	x		excess		0
(C) (moles)	0		excess		5/20 = 0.25

From the above balanced equation it is clear that :

$$x = 0.25 \text{ X } 2/1 = 0.5 \text{ mole}$$

$$moles_A = V_L X \ M_A$$

$$0.5 = V_L \ X \ 2$$

$$V_L = 0.25\ (L) = 250\ (mL)$$

Tutorial

Exercise 7 : 5 moles of substance A is mixed with 10 moles of substance B and the volume is completed to one liter . The following reaction is occurred

$$A + 2B \leftrightarrow AB_2 \quad , \quad K_{eq} = 1 \times 10^{10}$$

Calculate the molar concentrations of A and B at equilibrium ?

Your answer :

Our answer next slide

Tutorial

Answer 7 :

	A	+ 2 B	$\leftrightarrow$	AB_2 , $K_{eq} = 1 \times 10^{10}$
(I) (moles)	5	10		0
(C) (moles)	0	0		5
(E) (moles)	x	2 x		(5 – x)

$$K_{eq} = 1X10^{10} = \frac{5-x}{(x)(2x)^2} \approx \frac{5}{4x^3} \quad \therefore\ x = 5X10^{-4}\ M$$

$[B] = 2 \text{ X } 5\text{X } 10^{-4} = 1.0 \text{ X } 10^{-3}$ M

$[A] = 5 \text{ X } 10^{-4}$ M

Tutorial

To understand what is happening at equilibrium look at this video .

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Tutorial

Exercise 8 : 2.74 g of Ba^{2+} (aw = 137) is mixed with 5.13 g of IO_3^- (mw = 171).The volume is completed to 500 mL.The following complete reaction is occurred :

$$Ba^{2+} + 2\,IO_3^- \rightarrow Ba(IO_3)_2$$

Calculate (a) the weight of the formed precipitate $Ba(IO_3)_2$ (mw=308) (b) the molar concentration of the excess reactant in solution ?

Your answer :

Our answer next slide

Tutorial

Answer 8 :

	Ba^{2+}	+	$2\ IO_3^-$	$\rightarrow$	$Ba(IO_3)_2$
(I) (moles)	2.74 / 137 = 0.02		5.13 / 171 = 0.03		0
(C) (moles)	0.02 – 0.015 = 0.005		0		0.015

(a) wt. $Ba(IO_3)_2$ = 0.015 X 308 = 4.62 g

(b) $$[Ba^{2+}] = \frac{0.005\ (mole)}{500\ (mL)\ X\ 10^{-3}\ (L)} = 0.01\ M$$

Tutorial

Exercise 9 : 6 moles of substance B is mixed with 2 moles of substance A . The volume is completed to one liter . The following reaction is occurred :

$$A + 2B \leftrightarrow E + 2D \quad , \quad K_{eq} = 1 \times 10^{-3}$$

Calculate the molar concentration of B and D at equilibrium ?

Your answer :

Our answer next slide

Tutorial

Answer 9 :

	A	+	2 B	$\leftrightarrow$	E	+	2 D	, $K_{eq} = 1X10^{-3}$
(I) (moles)	2		6		0		0	
(E) (moles)	(2 –x)		(6 –2 x)		x		2x	

$$K_{eq} = 1x10^{-3} = \frac{(x)(2x)^2}{(2-x)(6-2x)^2} \approx \frac{4x^3}{(2)(6)^2} = \frac{4x^3}{72} = \frac{x^3}{18}$$

$$x = 3\sqrt{1x10^{-3}\,X18} = 0.26\ mole = [E]$$

$$[B] = \frac{[6-(2X0.26)]moles}{1(L)} = 5.48\ M$$

Tutorial

Exercise 10 :

Calculate the weight of $AgNO_3$ (mw = 170) required to convert 2.33 g of Na_2CO_3 (mw = 106) to Ag_2CO_3 (mw = 275.7) according to the following reaction :

$$Na_2CO_3 + 2AgNO_3 \rightarrow Ag_2CO_3 + 2\,NaNO_3$$

Calculate the weight of the formed Ag_2CO_3 ?

Your answer :

Our answer next slide

Tutorial

Answer 10 :

	Na_2CO_3	+	$2\ AgNO_3 \rightarrow$	Ag_2CO_3	+	$2\ NaNO_3$
(I) (moles)	2.33/106 = 0.02		0.04	0		0
(C) (moles)	0		0	0.02		0.04

moles $AgNO_3$ = moles Na_2CO_3 X 2/1 = 0.02 X 2/1 = 0.04

wt. $AgNO_3$ = 0.04 X 170 (mw) = 6.8 g

wt. Ag_2CO_3 = 0.02 X 275.7 = 5.5 g

Tutorial

Exercise 11 : 200 g of Na_2CO_3 (mw=106) is mixed with 500 g of $AgNO_3$ (mw=170) . Water is added to complete the volume to 500 mL . The following complete reaction is occurred :

$$Na_2CO_3 + 2\,AgNO_3 \rightarrow Ag_2CO_3 + 2\,NaNO_3$$

(1) Which is the limiting reactant ? (2) Calculate the weight of the produced Ag_2CO_3 (mw = 275.7) ? (3) Calculate the molar concentration of the produced $NaNO_3$?

Your answer :

Our answer next slide

Tutorial

Answer 11 :

	Na_2CO_3 +	$2\,AgNO_3$ →	Ag_2CO_3 +	$2\,NaNO_3$
(I) (moles)	200/106= 1.9	500/170=2.9	0	0
(C) (moles)	0.45	0	1.45	2.9

(1) The limiting reactant is $AgNO_3$ because it has completely converted to products.

(2) Wt. Ag_2CO_3 = 1.45 X 275.7 (mw) = 399.77 g

(3) $$[NaNO_3] = \frac{2.9\,(moles)}{500\,(mL)\,X\,10^{-3}\;(L)} = 5.8\ M$$

Tutorial

Exercise 12 : It is required to prepare 750 g of Ag_2CO_3 (mw = 275.7) according to the following reaction : $Na_2CO_3 + 2\ AgNO_3 \rightarrow Ag_2CO_3 + 2\ NaNO_3$

(1) Calculate the weight of $AgNO_3$ (mw = 170) that should be added to an excess of Na_2CO_3

(2) Calculate the volume of 10 M solution of Na_2CO_3 that should be added to an excess of $AgNO_3$ to obtain 750 g of Ag_2CO_3 ?

Your answer :

Our answer next slide

Tutorial

Answer 12 :

Na_2CO_3	+	$2\ AgNO_3$	$\rightarrow$	Ag_2CO_3	+	$2\ NaNO_3$	
excess		؟		750/275.7=2.7		5.4 moles	(١)
?		excess		2.7 moles		5.4 moles	(٢)

(1) moles $AgNO_3$ = moles Ag_2CO_3 X 2/1= 2.7 X 2/1 = 5.4 moles

Wt. $AgNO_3$ = 5.4 X 170 = 918 g

(2) moles Na_2CO_3 = moles Ag_2CO_3 = 2.7

$$10\ M = \frac{2.7\ (moles)}{V_L}$$

$$V_L = \frac{2.7}{10} = 0.27\ (L) = 270\ (mL)$$

Tutorial

Exercise 13 : Calculate the weight of the Ag_2CO_3 (mw = 106) that produced from mixing 25 mL 0.2 M $AgNO_3$ solution with 50 mL 0.1 M Na_2CO_3 according to the following equation : $Na_2CO_3 + 2\ AgNO_3 \rightarrow Ag_2CO_3 + 2\ NaNO_3$

Your answer :

Our answer next slide

Tutorial

Answer 13 :

	Na_2CO_3 +	$2\ AgNO_3$ $\rightarrow$	Ag_2CO_3 +	$2\ NaNO_3$
(I) (mmoles)	50 x 0.1= 5	25X0.2=5	0	0
(C) (mmoles)	2.5	0	2.5	5

Weight of Ag_2CO_3 = 2.5 X 275.7 = 689.25 mg

على الراغبين الاستماع الى محاضرات الاستاذ الدكتور/ ابراهيم زامل الزامل باللغة العربية عن هذا الموضوع الرجوع الى الروابط التالية :

العلاقات الكمية و الاتزان الكيميائي في التفاعلات الكيميائية

العلاقات الكمية و الاتزان الكيميائي في التفاعلات الكيميائية ٢

العلاقات الكمية و الاتزان الكيميائي في التفاعلات الكيميائية ٣

العلاقات الكمية و الاتزان الكيميائي في التفاعلات الكيميائية ٤