

Chemical Kinetics

Chemical kinetics  $\rightarrow$  It is branch of a science which deals with the study of rate of reaction and factors on which rate of reaction depends.

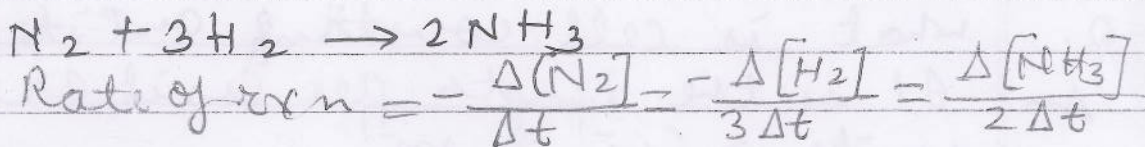
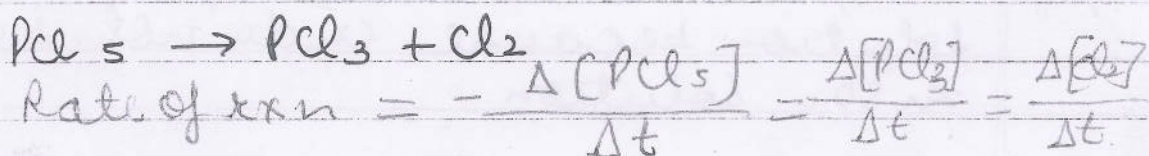
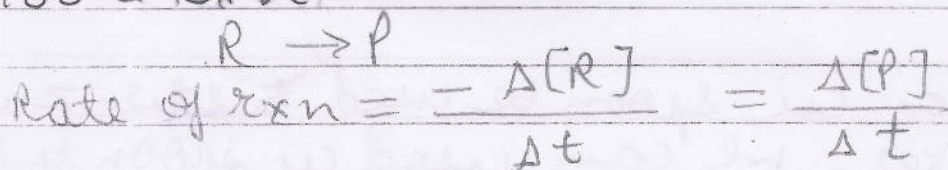
Rate of rxn  $\rightarrow$  Rate of rxn may be defined as change in concentration of the reactant or product per unit time.

Mathematically  $\rightarrow$

$$\text{Rate of rxn} = \frac{\text{Dec. in conc. of reactant}}{\text{time taken}}$$

$$\text{Rate of rxn} = \frac{\text{Inc. in conc. of product}}{\text{time taken}}$$

For a rxn



Rate of rxn can be express in two ways:

- 1) Average rate
- 2) Instantaneous rate

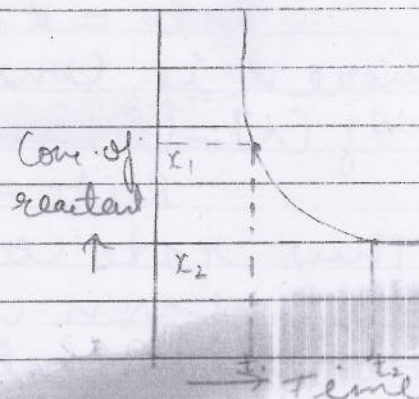
Average rate  $\rightarrow$  Average rate of a rxn may be defined as change in conc. of the reactant or product per unit time is

It is average rate.

Average rate of a rxn can be calculated by plotting a graph b/w the concentration of the reactant and time.

$$\text{Rate of rxn} = -\frac{\Delta[R]}{\Delta t}$$

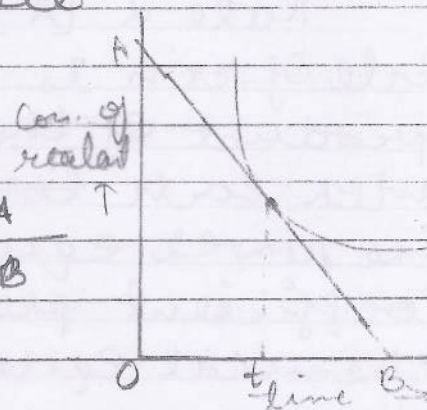
$$= \frac{-(x_2 - x_1)}{(t_2 - t_1)}$$



Instantaneous rate  $\rightarrow$  The rate of a rxn at particular instant of a time is called instantaneous rate.

$$\text{Rate (ins)} = \lim_{\Delta t \rightarrow 0} -\frac{\Delta[R]}{\Delta t}$$

$$\text{Rate (ins)} = -\text{slope} = -\frac{OA}{OB}$$



Factors on which rate of a rxn depends  $\rightarrow$

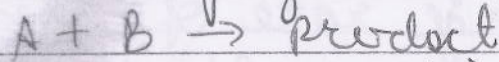
- 1) Nature of reactant and product
- 2) Surface area
- 3) Conc. of the reactant
- 4) Temperature
- 5) Presence of Catalyst

Dependence of rate of rxn on the conc. of the reactant  $\rightarrow$

Law of mass action  $\rightarrow$  Acc. to this law the

rate of a rxn is directly proportional to the product of molar conc. of reactant.

mathematically for a rxn



Acc to law of mass action

$$\text{Rate} \propto [A][B]$$

$$\text{Rate} = k [A][B]$$

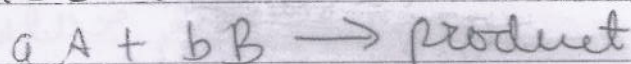
where  $k$  is constant and  $k$  is rate constant.

$$\text{If } [A] = [B] = 1$$

$$\text{Rate} = k$$

Thus rate constant is equal to the rate of rxn when the molar conc. of the reactant is taken as unity.

For a rxn



Acc to law of mass action

$$\text{Rate} \propto [A]^a [B]^b$$

Rate of rxn is directly proportional to the product of the molar conc. of reactant with each term conc. term raise to the power equal to the stoichiometric coefficient present in the balance chemical equation.

Rate law  $\Rightarrow$  (dependence of rate of rxn on the conc. of the reactant determine experimentally)  $\rightarrow$  Rate law explains the relationship b/w rate of a rxn and conc. of the reactant determine experimentally.

Acc. to this law the rate of rxn

is directly proportional to the product of molar conc. of reactant with each conc. term raise to the power equal to a number determine experimentally.

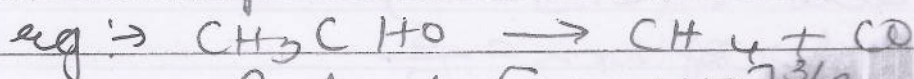
For a rxn



Acc to rate law

$$\text{Rate} \propto [A]^x [B]^y$$

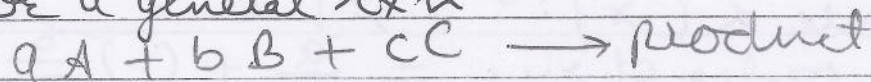
This expression is called rate law expression



$$\text{Rate} \propto [\text{CH}_3\text{CHO}]^{3/2}$$

Order of rxn  $\rightarrow$  It is defined as the sum of the powers to which conc. term are raised in rate law expression.

For a general rxn



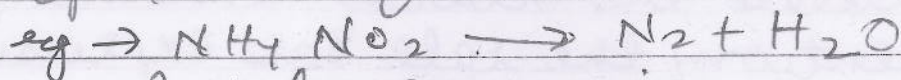
acc. to rate law

$$R \propto [A]^x [B]^y [C]^z$$

$$\text{order of a rxn} = x + y + z$$

There are following types of rxn

1) 1<sup>st</sup> order rxn  $\rightarrow$  The rxn with order of rxn is equal to 1

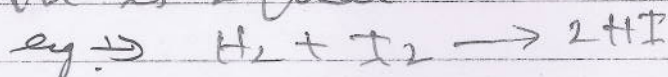


Rate law expression

$$\text{Rate} \propto [\text{NH}_4\text{NO}_2]$$

$$\therefore \text{order of rxn} = 1$$

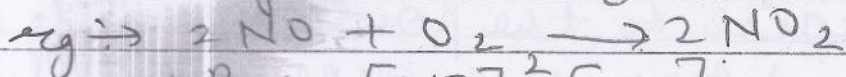
2) 2<sup>nd</sup> order rxn  $\rightarrow$  The rxn with order of rxn is equal to 2



Rate  $\propto [H_2][I_2]$

$\therefore$  order of rxn =  $1+1 = 2$

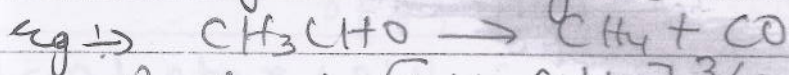
3) 3rd order of rxn  $\rightarrow$  The rxn with order of rxn is equal to 3.



Rate  $\propto [NO]^2 [O_2]$

$\therefore$  order of rxn =  $2+1 = 3$

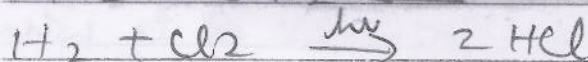
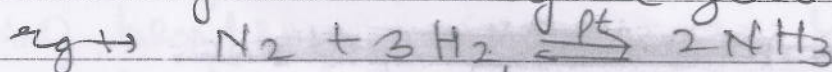
$\Rightarrow$  order of rxn may be in fraction



Rate  $\propto [CH_3CHO]^{3/2}$

$\therefore$  order of rxn =  $\frac{3}{2}$

$\Rightarrow$  order of rxn may be zero



Q. Rate  $\propto [x]^{a/3} [y]^{-b/2}$

$$\text{order of rxn} = \frac{a}{3} + (-1)\frac{b}{2}$$

$$= \frac{a}{3} - \frac{b}{2}$$

$$= \frac{2a - 3b}{6}$$

\* units of rate of reaction =  $\text{mol l}^{-1} \text{sec}^{-1}$

Q. Calculate the order of a reaction for a reaction, the rate law expression for this

$$\text{Rate} = k [A]^{3/2} [B]^{-1}$$

$$\text{order of rxn} = \frac{3}{2} - 1$$

$$= \frac{3-2}{2} = \frac{1}{2}$$

Q. The rxn has  $A + B \rightarrow C$  zero order of rxn. write the rate law expression  

$$\text{Rate} \propto [A]^0 [B]^0$$

Q. The concentration of reactant of a second order rxn is reduced to  $\frac{1}{2}$ . How its rate will be affected.  $A \rightarrow B$   $\text{Rate} = k[A]^2$   

$$\text{Rate} = k \left[ \frac{A}{2} \right]^2$$

$$\text{Rate} = k \frac{[A]^2}{4}$$

\* Units of rate constant  $\rightarrow$   
 For zero order rxn  
 $R \rightarrow P$

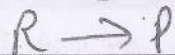
$$\text{Rate} = k[R]^0$$

$$\text{Rate} = k$$

$$\boxed{k = \text{mol l}^{-1} \text{sec}^{-1}}$$

For first order rxn  
 $R \rightarrow P$

let us consider 1st order rxn



$$\text{Rate} = k[R]^1$$

$$k = \frac{\text{Rate}}{[R]}$$

$$k = \frac{\text{mol l}^{-1} \text{sec}^{-1}}{\text{mol l}^{-1}}$$

$$\boxed{k = \text{sec}^{-1}}$$

For 2nd order rxn

let us consider 2nd order rxn



$$\text{Rate} = k[R]^2$$

$$k = \frac{\text{Rate}}{[R]^2}$$

$$k = \frac{\text{mol l}^{-1} \text{sec}^{-1}}{\text{mol}^2 \text{l}^{-2}}$$

$$k = \text{mol}^{-1} \text{l sec}^{-1}$$

For  $n^{\text{th}}$  order rxn

The units of rate constant  $k = (\text{mol l}^{-1})^{1-n} \text{sec}^{-1}$

Q. The value of rate constant for a rxn is

$$k = 3.4 \times 10^{-4} \text{ sec}^{-1}$$

What will be the order of rxn

Ans. 1<sup>st</sup> order of rxn

Q. What is the order of a rxn whose rate constant has same unit as that of rate of rxn?

Ans. Zero order of rxn

\* Molecularity of a reaction  $\rightarrow$  The number of reacting species (atoms, molecules or ions) which are colliding simultaneously in order to carry out a chemical rxn is called molecularity of a rxn.

If the molecularity of a rxn is one then the rxn is called unimolecular rxn. If the molecularity of a rxn is two then the rxn is called bimolecular rxn and so on.

Difference b/w Order of rxn and molecularity

	Order of rxn	Molecularity
1)	It is the sum of the powers of the conc. term in the rate law expression.	It is the number of reacting species which are colliding simultaneously in order to carry out a chemical reaction.
2)	It is a experimental concept.	It is a theoretical concept.
3)	Mol order of rxn may be zero.	molecularity can't be zero.
4)	order of rxn may be in fraction.	molecularity can't be in fraction.

\* Integrated rate law expression →

⇒ For zero order rxn  
let us consider a zero order rxn  
 $R \rightarrow P$

let  $[R]_0$  be the initial concentration of the reactant and  $[R]$  be the conc. of reactant at time  $t$ .

∴ Rate  $\propto [R]^0$   
Rate =  $k_0 \times 1$   
=  $k_0$

where  $k_0$  is rate constant or specific rate constant for zero order rxn.

$$- \frac{d[R]}{dt} = k_0$$

$$- d[R] = k_0 dt$$

On integrating both sides



$$- \int d[R] = k_0 \int dt + I$$

Where  $I$  is a constant of integration.

$$-[R] = k_0 t + I \quad \text{--- (1)}$$

At  $t = 0$  or  $[R] = [R]_0$

$$-[R]_0 = k_0 \times 0 + I$$

$$-[R]_0 = I$$

$$I = -[R]_0$$

Putting these values in equation (1)

$$-[R] = k_0 t + (-[R]_0)$$

$$-[R] = k_0 t - [R]_0$$

$$[R]_0 - [R] = k_0 t$$

$$k_0 = \frac{1}{t} ([R]_0 - [R]) \quad \text{--- (2)}$$

Let  $a$  be the initial concentration of the reactant and during time  $t$ ,  $x$  amount of reactant converted into product.

$\therefore$  At time  $t$  the concentration of the reactant will be  $a - x$

$$[R]_0 = a$$

$$[R] = a - x$$

Putting these values in equation (2)

$$k_0 = \frac{1}{t} (a - (a - x))$$

$$k_0 = \frac{1}{t} x$$

$$k_0 = \frac{x}{t}$$

This is another form of integrated rate law expression for zero order rxn.

⇒ For 1<sup>st</sup> order rxn

Let us consider a first order rxn  
 $R \rightarrow P$

Let  $[R]_0$  be the initial concentration of the reactant and  $[R]$  be the conc. of reactant at time  $t$ .

∴ Rate of  $[R]$

$$\text{Rate} = k_1 [R]$$

where  $k_1$  is the rate constant or specific rate constant for 1<sup>st</sup> order rxn.

$$-\frac{d[R]}{dt} = k_1 [R]$$

$$-\frac{d[R]}{[R]} = k_1 dt$$

on integrating both sides

$$-\int \frac{d[R]}{[R]} = k_1 \int dt + I \quad \left[ \because \frac{dx}{x} = \ln x \right]$$

$$-\ln[R] = k_1 t + I \quad \text{--- (1)}$$

At  $t=0$  or  $[R] = [R]_0$

$$-\ln[R]_0 = k_1 \times 0 + I$$

$$-\ln[R]_0 = I$$

Putting the value of  $I$  in equation (1)

$$-\ln[R] = k_1 t + (-\ln[R]_0)$$

$$-\ln[R] = k_1 t - \ln[R]_0$$

$$\ln[R]_0 - \ln[R] = k_1 t \quad \left[ \because \log \frac{m}{n} = \log m - \log n \right]$$

$$\ln \frac{[R]_0}{[R]} = k_1 t$$

$$k_1 = \frac{1}{t} \ln \frac{[R]_0}{[R]}$$

$$k_1 = \frac{2.303}{t} \log \frac{[R]_0}{[R]} \quad \text{--- (2)}$$

Let  $a$  be the initial concentration of reactant and during time  $t$ ,  $x$  amount of reactant converted into product.

$\therefore$  At time  $t$  the conc. of the reactant will be  $a-x$ .

$$[R]_0 = a$$

$$[R] = a-x$$

$$k_1 = \frac{2.303}{t} \log \frac{a}{a-x}$$

Half life period  $\rightarrow$  Half life period of a rxn is defined as a time during which the concentration of the reactant is reduced to half. It is denoted by  $t_{1/2}$ .

$$\therefore \text{at } t = t_{1/2} \quad [R] = \frac{[R]_0}{2}$$

For a zero order rxn

$$t_{1/2} = \frac{[R]_0}{2k_0}$$

$$k_0 = \frac{1}{t} ([R]_0 - [R])$$

$$k_0 = \frac{1}{t_{1/2}} \left( [R]_0 - \frac{[R]_0}{2} \right)$$

$$k_0 = \frac{1}{t_{1/2}} \frac{[R]_0}{2}$$

$$t_{1/2} = \frac{[R]_0}{2k_0}$$

For 1<sup>st</sup> order rxn

$$t_{1/2} = \frac{0.693}{k_1}$$

It is clear from the above equation that half life period of

$$k_1 = \frac{2.303}{t} \log \frac{[R]_0}{[R]}$$

$$k_1 = \frac{2.303}{t}$$

$$t = \frac{2.303}{k_1} \log \frac{[R]_0}{[R]}$$

$$t_{1/2} = \frac{2.303}{k_1} \log \frac{[R]_0}{[R]_0/2}$$

1st order rxn is independent to the initial conc. of the reactant.

$$t_{1/2} = \frac{2.303}{k_1} \log 2$$

$$t_{1/2} = \frac{2.303}{k_1} \times 3.010$$

$$t_{1/2} = \frac{0.693}{k_1}$$

eg  $\Rightarrow$  Calculate the half life period of 1st order rxn. The specific rate constant of which is  $2 \text{ min}^{-1}$ .

sol.  $k = 2 \text{ min}^{-1}$

$$\therefore t_{1/2} = \frac{0.693}{2} = 0.3465 \text{ min}$$

eg  $\Rightarrow$  The rate constant for 1st order rxn is  $60 \text{ sec}$ . How much time will it take to reduce the concentration of the reactant to  $1/10^{\text{th}}$  of its initial value.

sol.  $\rightarrow$

$$k = 60$$

$$k = \frac{2.303}{t} \log \frac{[R]_0}{[R]}$$

$$t = \frac{2.303}{k} \log \frac{[R]_0}{[R]}$$

$$t = \frac{2.303}{60} \log \frac{[R]_0}{\frac{[R]_0}{10}}$$

$$t = \frac{2.303}{60} \log 10 \quad [\because \log 10 = 1]$$

$$t = \frac{2.303}{60}$$

$$t = 0.038 \text{ sec} \approx 3.8 \times 10^{-2} \text{ s}$$

eg  $\rightarrow$  The half life period of 1<sup>st</sup> order rxn is 2 min. How long will it take to reach 10% of its concentration?

Sol.

$$t_{1/2} = 2$$

$$t_{1/2} = \frac{0.693}{k}$$

$$k = \frac{0.693}{t_{1/2}}$$

$$k = \frac{0.693}{2}$$

$$k = 0.346$$

$$t = \frac{2.303}{k} \log \frac{[R]_0}{[R]}$$

$$t = \frac{2.303}{0.346} \log \frac{100}{10}$$

$$t = \frac{2.303}{0.346} \log 10$$

$$t = \frac{2.303}{0.346}$$

$$t = 6.65$$

eg  $\rightarrow$  A 1<sup>st</sup> order rxn takes 40 min. for 30% completion. Calculate  $t_{1/2}$  for this rxn?

Sol.

~~$$t_{1/2} = \frac{0.693}{k}$$~~

$$k = \frac{2.303}{40} \log \frac{[R]_0}{[R]}$$

$$k = \frac{2.303}{40} \log \frac{100}{100}$$

$$k = \frac{2.303}{40} \log \frac{1}{0.70}$$

$$k = \frac{2.303}{40} \times 0.1549$$

$$k = 8.92 \times 10^{-3} \text{ min}^{-1}$$

$$t_{1/2} = \frac{0.693}{k}$$

$$t_{1/2} = \frac{0.693}{8.92 \times 10^{-3} \text{ min}^{-1}}$$

$$t_{1/2} = 77.7 \text{ min.}$$

Q.11

Show that time required for 99% comp of a 1<sup>st</sup> order rxn is twice the time required for the completion of 90% rxn

Ans

For a first order rxn

$$t = \frac{2.303}{k} \log \frac{[A]_0}{[A]}$$

Let initial conc,  $[A]_0 = a$

For 99% completion of rxn,

$$\begin{aligned} t_{99\%} &= \frac{2.303}{k} \log \frac{100}{1} \\ &= \frac{2.303}{k} \log 100 \\ &= \frac{2.303 \times 2}{k} \quad \text{--- (1)} \end{aligned}$$

For 90% completion of rxn

$$\begin{aligned} t_{90\%} &= \frac{2.303}{k} \log \frac{100}{10} \\ &= \frac{2.303 \times 1}{k} \quad \text{--- (2)} \end{aligned}$$

Dividing eq. ① by ②

$$\frac{k(99\%)}{k(90\%)} = 2$$

$$k(99\%) = 2 \times k(90\%)$$

Q.  $\Rightarrow$  A rxn is 1<sup>st</sup> order in reactant A and second order reactant B. How the rate affected when concentration of both A & B are double?

Sol.  $\Rightarrow$

$$\text{Rate} \propto [A]^1 [B]^2$$

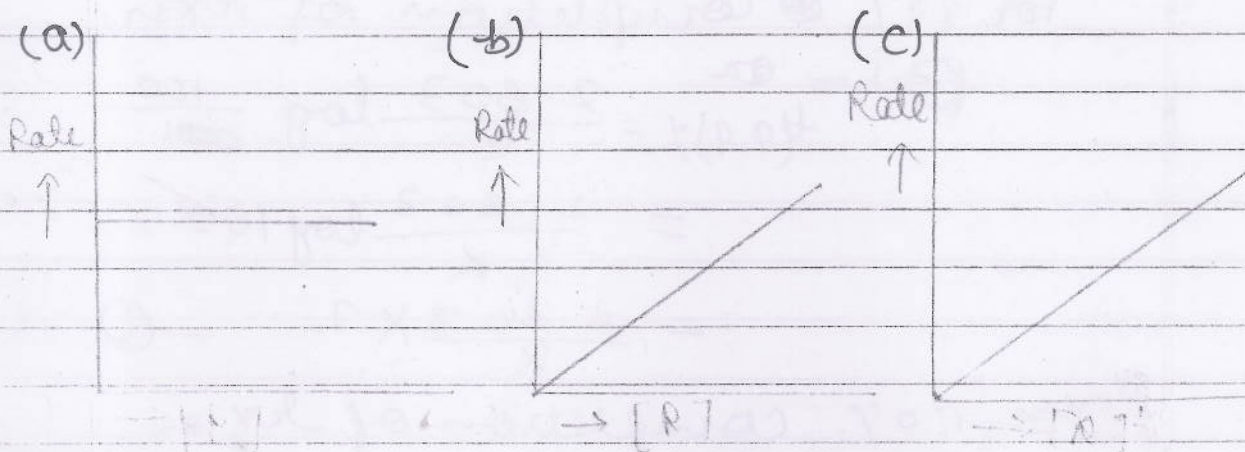
$$\text{Rate} \propto [2A] [2B]^2$$

$$\text{Rate} \propto [2A] [4B] = 8 \text{ times increase}$$

\* Experimental determination of order of rxn  $\rightarrow$

Experimentally order of rxn can be determined by following method  $\rightarrow$

1) Graphical method  $\rightarrow$  This method is used when there is only one reactant present in the rxn. In this method a graph is plotted b/w rate of rxn vs concentration of reactant [R].



If the graph is a 'a' then rxn is zero order  
 If graph is 'b' then 'b' graph is obtained  
 then rxn is 1<sup>st</sup> order.

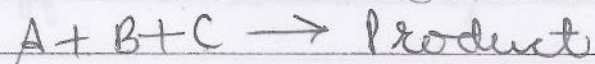
If neither 'a' nor 'b' graph is  
 obtained then graph is plotted b/w  
 rate v/s  $[R]^2$  - If graph is line 'c' then  
 the order of rxn is 2<sup>nd</sup> order.

Similarly, the higher order of rxn can  
 be obtained by plotting a graph b/w  
 rate v/s  $[R]^3, [R]^4$  - - - so on.

2) Ostwald method  $\rightarrow$  This method is used  
 for finding the order of rxn containing  
 more than one reactant.

This method is based on the  
 principle that if concentration of all  
 reactant or except one reactant is taken  
 in excess then the rate of rxn do not  
 depends upon the concentration of reactant  
 that taken in excess.

Let us consider a rxn



If B and C are taken in excess then the  
 Rate  $\propto [A]^x$  - (1)

If A and C are taken in excess then the  
 Rate  $\propto [B]^y$  - (2)

If A and B are taken in excess then the  
 Rate  $\propto [C]^z$  - (3)

Now, from equation (1), (2) & (3)

$$\text{Rate} \propto [A]^x [B]^y [C]^z$$

$$\therefore \text{order of rxn} = x + y + z$$



Dependence of rate of rxn on temperature  $\rightarrow$   
 The rate of rxn increases with increase in temperature. The rate of rxn almost becomes double for every  $10^\circ\text{C}$  rise in temperature.

This can be explain due to collision theory. According to collision theory

Rate of rxn  $\propto$  Collision frequency ( $Z$ ) and effective collision ( $f$ )

Temp. coefficient  $\rightarrow$   
 It is the ratio of rate constant of a rxn at two different temperature differ by  $10^\circ\text{C}$ .

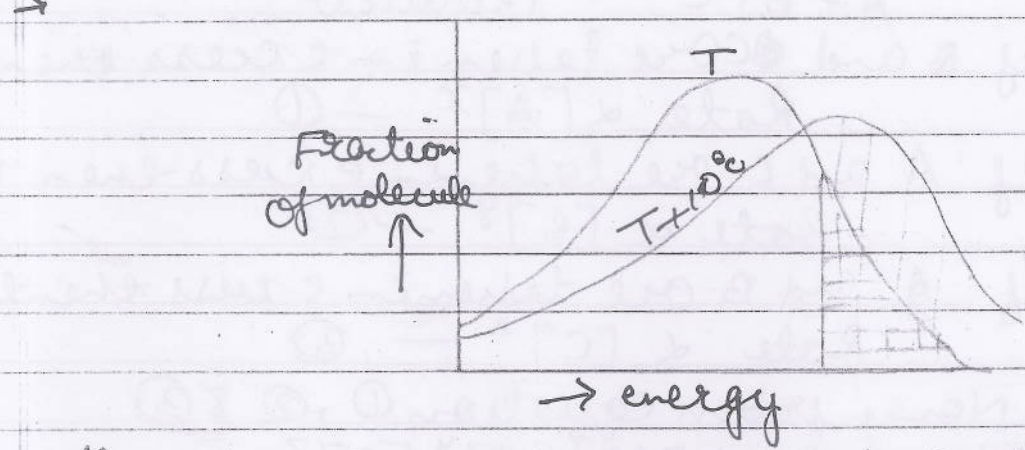
$$\text{Temp. Coeff} = \frac{\text{Rate Const. at } T+10^\circ}{\text{Rate Const. at } T}$$

Rate  $\propto Z \times f$  [ where  $Z =$  collision frequency  
 $f =$  effective collision ]

Effect of temperature on collision frequency  $\rightarrow$   
 $Z \propto \downarrow$  Temperature

Thus for  $10^\circ\text{C}$  rise in temperature, the collision frequency increases upto 3%.

Effect of temperature on effective collision  $\rightarrow$



It is clear from the graph of fraction of

molecule and energy the molecules with effective collision almost becomes double for  $10^\circ\text{C}$  rise in temperature. Thus for 10 rise in temperature the effective collision becomes almost double and the rate of rxn also becomes double.

\* Arrhenius equation  $\rightarrow$  (Relationship b/w rate constant and temperature)  $= k \rightarrow$  Arrhenius equation is a relationship b/w rate constant and temperature. Ac to Arrhenius equation the relationship b/w rate constant and temperature is

$$k = Ae^{-E_a/RT}$$

where  $k$  = rate constant

$T$  = temperature

$A$  = constant  $k$  is Arrhenius constant factor or frequency factor

$e$  = exponential

$E_a$  = activation energy

$R$  = gas constant ( $8.314 \text{ J mol}^{-1}$ )

$A, E_a$  are collectively  $k$  is Arrhenius parameters.

Arrhenius equation

$$k = Ae^{-E_a/RT} \quad \text{--- (1)}$$

Taking  $\ln$  both sides

$$\ln k = \ln A - \frac{E_a}{RT} \quad [\because \ln e^x = x]$$

$$2.303 \log k = 2.303 \log A - \frac{E_a}{RT}$$

$$\log k = \log A - \frac{E_a}{2.303RT}$$

Let  $k_1$  be the rate constant at temperature  $T_1$ , and  $k_2$  be the rate constant at temperature  $T_2$ .

In terms of  $k_1$

$$\log k_1 = \log A - \frac{E_a}{2.303RT_1} \quad \text{--- (2)}$$

In terms of  $k_2$

$$\log k_2 = \log A - \frac{E_a}{2.303RT_2} \quad \text{--- (3)}$$

Now subtract equation (2) from (3)

$$\log k_2 - \log k_1 = \log A - \frac{E_a}{2.303RT_2} - \left[ \log A - \frac{E_a}{2.303RT_1} \right]$$

$$\log k_2 - \log k_1 = -\frac{E_a}{2.303RT_2} + \frac{E_a}{2.303RT_1}$$

$$\log k_2 - \log k_1 = \frac{E_a}{2.303R} \left[ \frac{1}{T_1} - \frac{1}{T_2} \right]$$

$$\boxed{\log \frac{k_2}{k_1} = \frac{E_a}{2.303R} \left[ \frac{T_2 - T_1}{T_1 \times T_2} \right]}$$

eg:  $\Rightarrow$  If we increase temperature of a rxn from 298K to 308K. The rate of rxn becomes double. What would be the value of activation energy ( $E_a$ ) for this rxn. ( $R = 8.314 \text{ J K}^{-1} \text{ mol}^{-1}$ )

Sol:  $\rightarrow$

$$T_1 = 298 \text{ K}$$

$$T_2 = 308 \text{ K}$$

$$\text{let } k_1 = k$$

$$k_2 = 2k$$

$$\log \frac{2k}{k} = \frac{E_a}{2.303 \times 8.314} \left[ \frac{308 - 298}{308 \times 298} \right]$$

$$\log 2 = \frac{E_a}{2.303 \times 8.314} \left[ \frac{10}{308 \times 298} \right]$$

el  
nature

$$0.3010 = \frac{E_a}{2.303 \times 8.314} \left[ \frac{10}{308 \times 298} \right]$$

$$E_a = \frac{0.3010 \times 2.303 \times 8.314 \times 308 \times 298}{10}$$

$$E_a = 52898 \text{ J mol}^{-1}$$

$$E_a = 52.898 \text{ kJ mol}^{-1}$$

eg  $\Rightarrow$

The rate of a rxn quadruples when the temperature changes from 293 to 313. Calculate the activation energy assuming the temperature remain same?

$E_a$   
 $2.303RT_1$

sol

$$T_1 = 293 \text{ K}$$

$$T_2 = 313 \text{ K}$$

$$\text{let } k_1 = k$$

$$k_2 = 4k$$

$$\log \frac{4k}{k} = \frac{E_a}{2.303 \times 8.314} \left[ \frac{313 - 293}{293 \times 313} \right]$$

$$\log 4 = \frac{E_a}{2.303 \times 8.314} \left[ \frac{20}{293 \times 313} \right]$$

rxn  
activation  
energy

$$0.6021 = \frac{E_a}{2.303 \times 8.314} \left[ \frac{20}{293 \times 313} \right]$$

$$E_a = \frac{0.6021 \times 2.303 \times 8.314 \times 293 \times 313}{20}$$

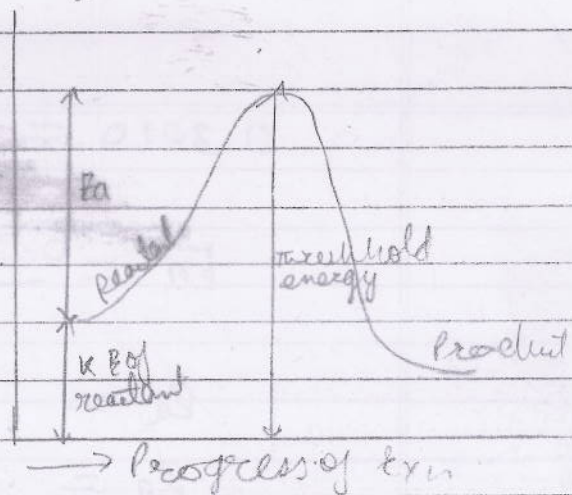
$$E_a = 52863.3 \text{ J mol}^{-1}$$

$$E_a = 52.86 \text{ kJ mol}^{-1}$$

\* Activation energy  $\rightarrow$  The excess energy which must be supplied to the reaction in order to carry out a chemical rxn is called as activation energy. Activation energy

Activation energy is denoted by  $E_a$  and mathematically  $\rightarrow$

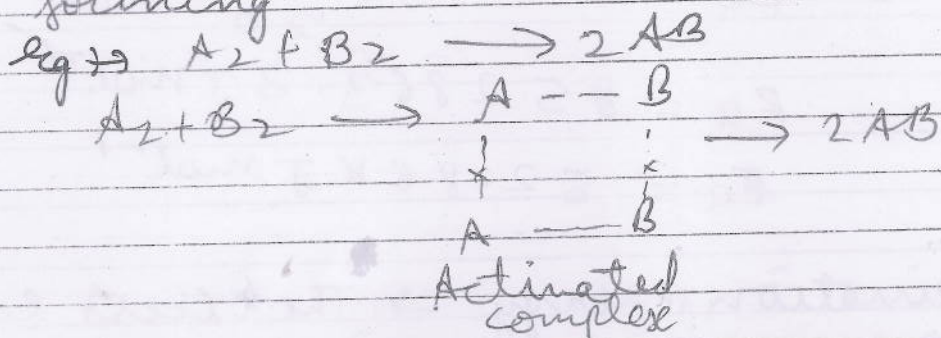
Activation energy  
- Threshold energy  
- Kinetic energy of reactants



$\Rightarrow$  Less be the activation energy of a rxn more be the rate of rxn and more be the activation energy less be the rate of a rxn.

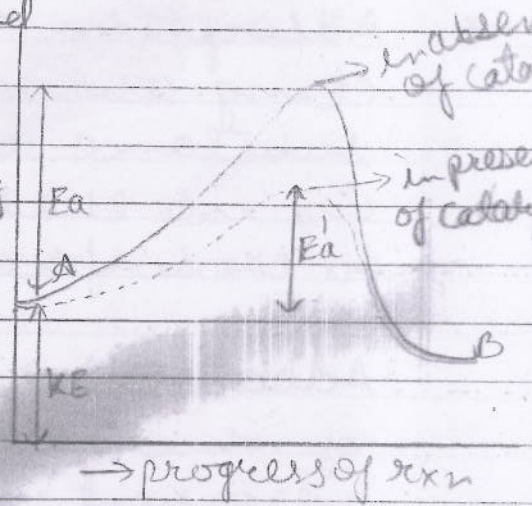
Activated complex theory  $\Rightarrow$  Acc. to this theory reactants are not directly converted into the products. The reactants are first converted into an intermediate compound called activated complex and these activated complex they change into product.

The stage at which activated complex is formed is called activated state or transition state. In this state the old bonds start breaking and the new bonds start forming.



\* Effect of presence of a catalyst on the rate of rxn → Catalyst is a substance which increases the rate of rxn without participating in the rxn.

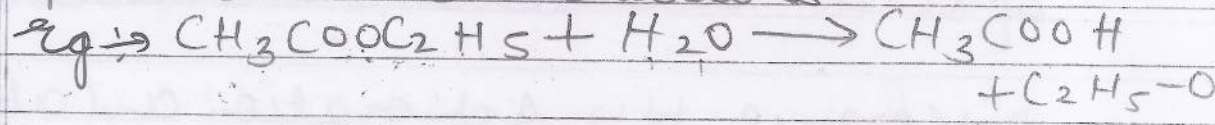
When a rxn is carried out in presence of a catalyst the catalyst form an Activated Energy complex with reactant which have lower activation energy than the uncatalysed rxn.



∴  $E_a' < E_a$

This means that the activation energy of a rxn becomes lower in presence of catalyst and due to lower activation energy the rate of rxn increases.

\* Pseudo chemical rxn → The rxn which appears to be of higher order but actually obey lower order kinetics are called pseudo chemical reactions.



This reaction appears to be of 2<sup>nd</sup> order but it obey 1<sup>st</sup> order kinetics because water is taken in excess.