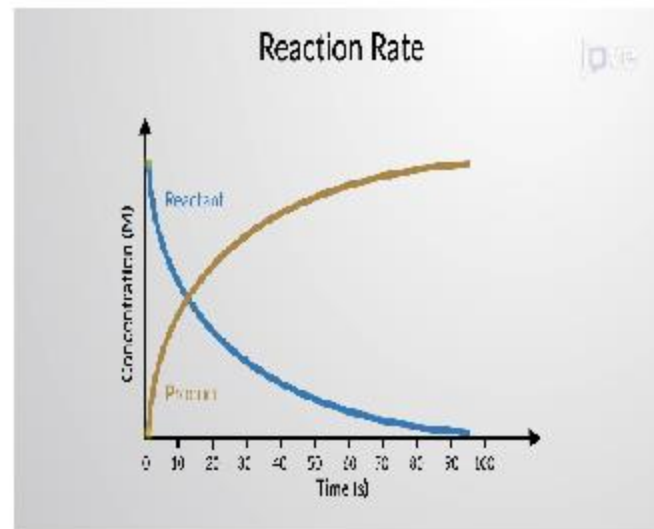


# **Unit 1**

# **Order of reaction**

**Dr. Shashi Kiran Misra**  
**Assistant Professor**  
**School of pharmaceutical Sciences**

# KINETICS



Kinetics is the study of the rate at which processes occur. It is useful in providing information that:

- ✓ Gives an insight into the mechanisms of changes involved, and
- ✓ Allows a prediction of the degree of the change that will occur after a given time has elapsed.

## RATE CONSTANT

A rate constant is a proportionality constant that appears in a rate law.

**For example**,  $k$  is the rate constant in the rate law  $d[A]/dt = k[A]$ .

Rate constants are independent of concentration but depend on other factors, most notably temperature.

## ORDER OF REACTION

This is the number of concentration terms that determine the rate.

Consider the reaction:



The rate of the reaction is proportional to the concentration of A to the power of  $x$ ,  $[A]^x$

and also the rate may be proportional to the concentration of B to the power of  $y$ ,  $[B]^y$ .

The overall equation is,

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

The overall order of reaction is  $x+y$

# Reaction Rate and Order

Reaction rate is the velocity of reaction to convert the reactants into its product.

Reactions may be classified according to the order of reaction, which is the number of reacting species whose concentration determines the rate at which the reaction occurs.

**The most important orders of reaction are**

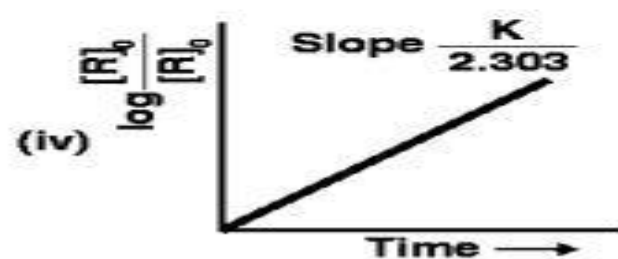
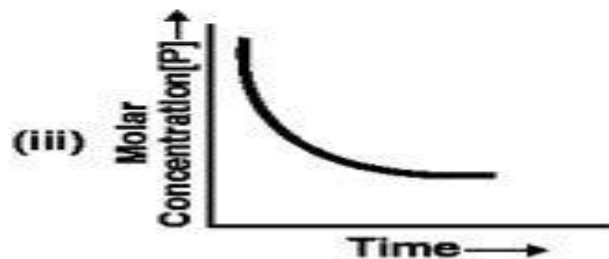
**zero-order** (breakdown rate is independent of the concentration of any of the reactants),

**first-order** (reaction rate is determined by one concentration term) and **second-order** (rate is determined by the concentrations of two reacting species).

The decomposition of many drugs can occur simultaneously by two or more pathways, which complicates the determination of rate constants.

# TYPES OF ORDER OF REACTION

1. Zero order reaction
2. First order reaction
3. Second order reaction
4. Pseudo order reaction



# ZERO ORDER REACTION

When the reaction rate is **independent of concentration** of the reacting substance, it depends on the zero power of the reactant and therefore is zero order reaction.

In this type of reaction, the limiting factor is something other than concentration, for example, solubility or absorption of light in certain photochemical reactions.

## **Example:**

- Loss of colour of multi-sulfa drug.

Rate of The rate of decomposition can be described mathematically as:

**Rate of concentration decrease;**

$$\frac{-dC_x}{dt} = K \dots \dots \dots (1)$$

The **unit of K** is **conc time<sup>-1</sup>**, with typical units of **mole L<sup>-1</sup> s<sup>-1</sup>**.

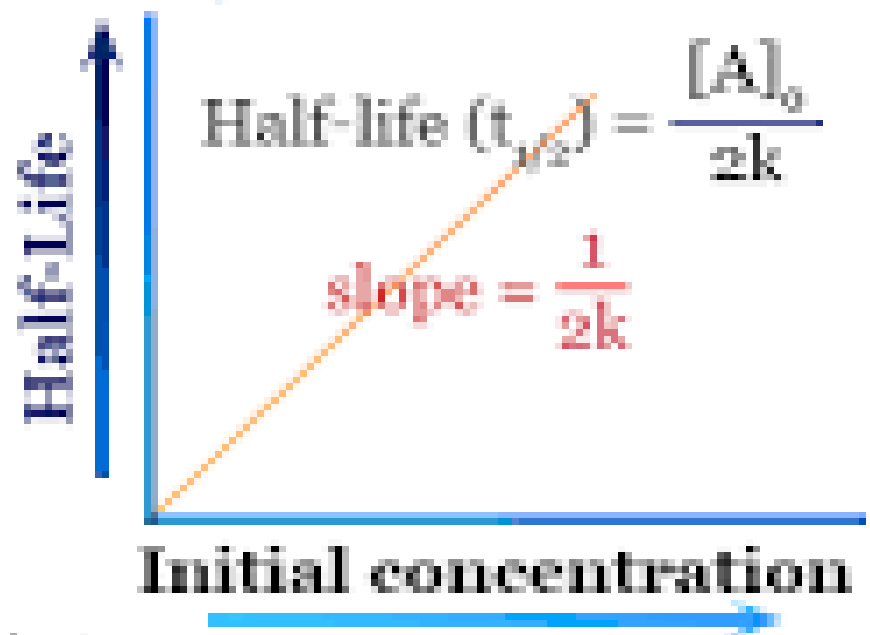
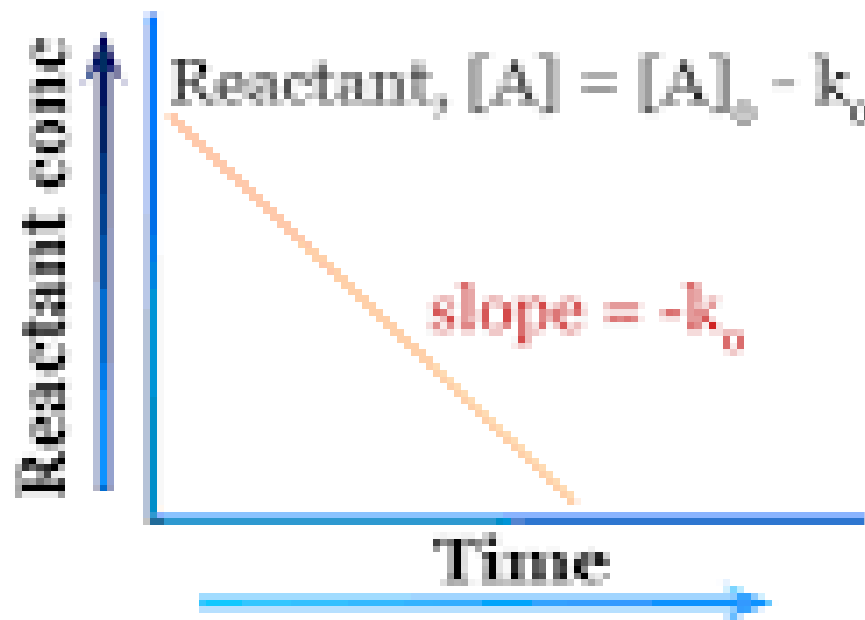
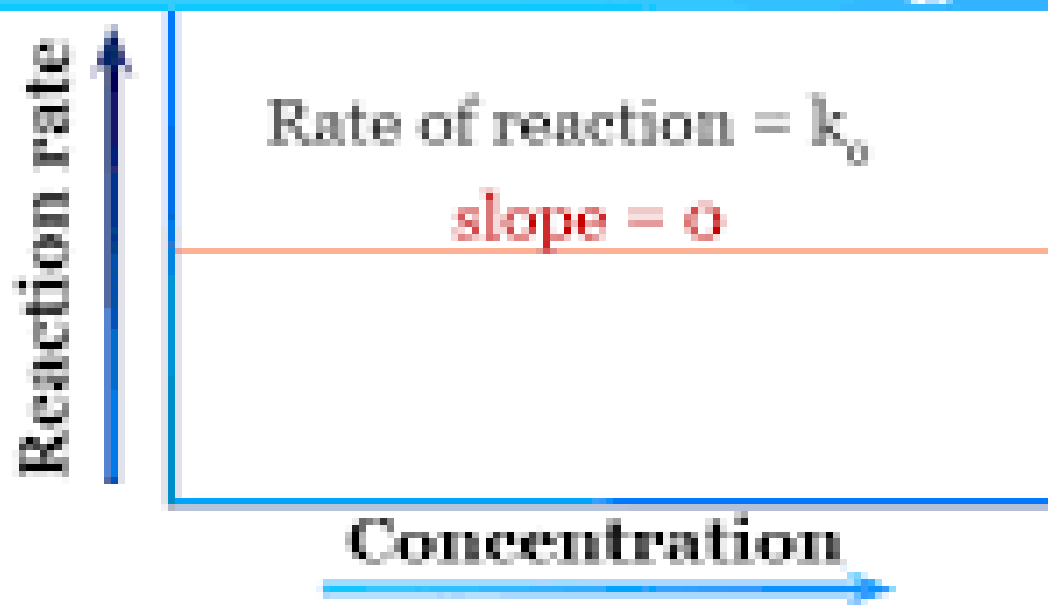
**Half-life is given by equation;**

$$t_{1/2} = C_0/2k$$

### **Examples: -**

- Vitamin A acetate to anhydrous vitamin A.
- Photolysis of cefotaxime.
- Loss in color of multi sulfa product.
- Intravenous infusion, Drug released from TDDS.

# Zero order reaction graph





# FIRST ORDER REACTION

When the reaction rate depends on the first power of concentration of a single reactant, it is considered to be **first order**.

## **Example are**

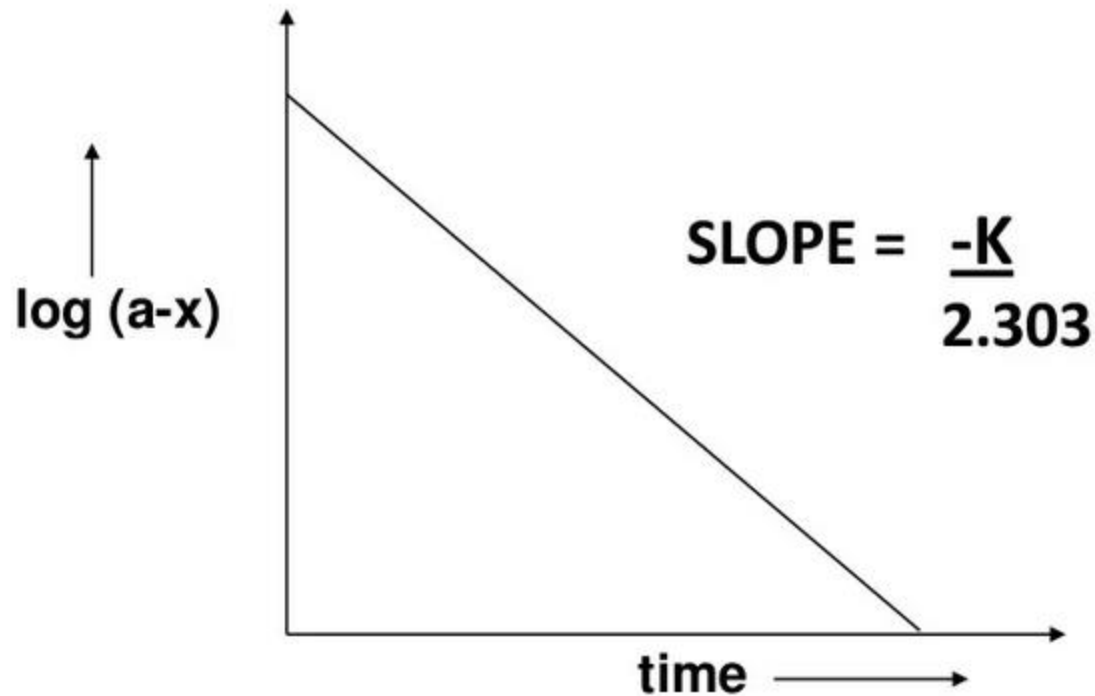
- Absorption, distribution, elimination rates.
- Microbial death kinetics.

Thus the rate of reaction is directly proportional to the concentration of reacting substance and can be expressed as follows:

**Rate of concentration decrease;**

$$-\frac{dC_x}{dt} = KCx \dots \dots \dots (1)$$

If first order law is obeyed then a graph of  $\log (a-x)$  v/s time  $t$  will give straight line with **slope of  $-K/2.303$**  and an intercept of  **$\log a$  at  $t = 0$** .



$$K = \frac{2.303 \log (a/a-x)}{t}$$

**Unit of K** for first order is **time<sup>-1</sup>** i.e. **SI unit** is **(sec)<sup>-1</sup>** because K is inversely proportional to t.

The **half-life**  $t_{1/2}$  of a drug is the time required for 50% of drug to degrade and can be calculated as follows:

$$\begin{aligned}t_{1/2} &= \frac{2.303 \log C_0}{k} = \frac{2.303 \log 100}{k} \\ &= \frac{2.303 \log 2}{k} = \frac{0.693}{k}\end{aligned}$$

**therefore**

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

**In pharmaceutical field** , the time required for 10% of the drug to degrade is an important value to know, since it represents a reasonable limit of degradation of active ingredients.

The  $t_{10\%}$  value can be calculated as

$$t_{10\%} = \frac{0.104}{k}$$

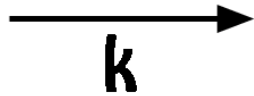
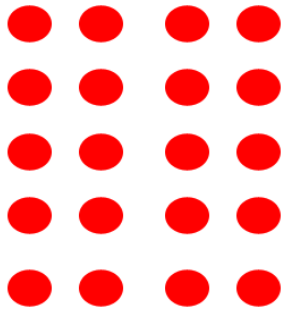
*or*

$$t_{10\%} = 0.152 t_{1/2}$$

### **Example**

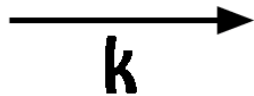
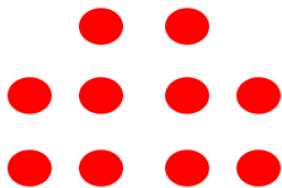
Decomposition rate of hydrogen peroxide, catalyzed by 0.02 molar KI.

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



A higher **initial concentration** has no impact on the time needed for **half** of the reactant to be **consumed**

For first-order reactions, the half-life does not depend on the initial quantity



A lower **initial concentration** has no impact on the time needed for **half** of the reactant to be **consumed**

## **PSEUDO-FIRST ORDER REACTION**

Here a second order or bimolecular reaction is made to behave like first order. This is found in the case in which one reacting material is present in great excess or is maintained at constant concentration as compared with other substance. Here reaction rate is determined by one reactant even though two are present.

### **EXAMPLES:**

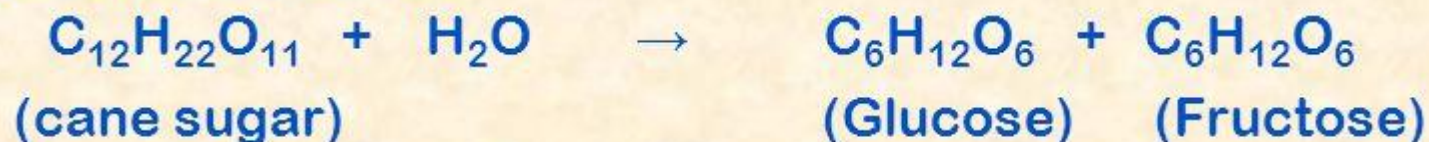
- Decomposition of ascorbic acid tablet.
- Aspirin hydrolysis.

# Pseudo First Order Reaction

Such reactions in which the molar concentration of a reactant remains practically unchanged and the small change in concentration does not effect the rate of reaction are called Pseudo First Order Reaction.

Example:

Hydrolysis of Sucrose –



Hydrolysis of Ester –



# First Order vs Pseudo First Order Reaction

More Information Online [WWW.DIFFERENCEBETWEEN.COM](http://WWW.DIFFERENCEBETWEEN.COM)

	First Order Reaction	Pseudo First Order Reaction
DEFINITION	First order reactions are chemical reactions where the rate of reaction depends on the molar concentration of one of the reactants involved in the reaction	Pseudo first order reactions are second order chemical reactions that are made to behave as first order reactions
ORDER OF REACTION	First order reaction	Second order reaction
NATURE OF THE REACTION	Rate of the reaction depends on one reactant concentration	Rate of the reaction depends on two reactants, but it appears to be only on one reactant because the concentration of the other reactant is very high so that the change in concentration appears to be negligible



# SECOND ORDER REACTION

Rate of change in conc. of product and reactant is dependent on **second power of conc. of single reactant or to first powers of the conc. of two reactants.**"

$$\text{i.e. } -\frac{dC_X}{dt} = K [X] [Y] \text{-----(1)}$$

$$\text{or } -\frac{dC_X}{dt} = K [X]^2 \text{-----(2)}$$

Let us discuss;  $-\frac{dC_X}{dt} = K [X] [Y]$  in detail

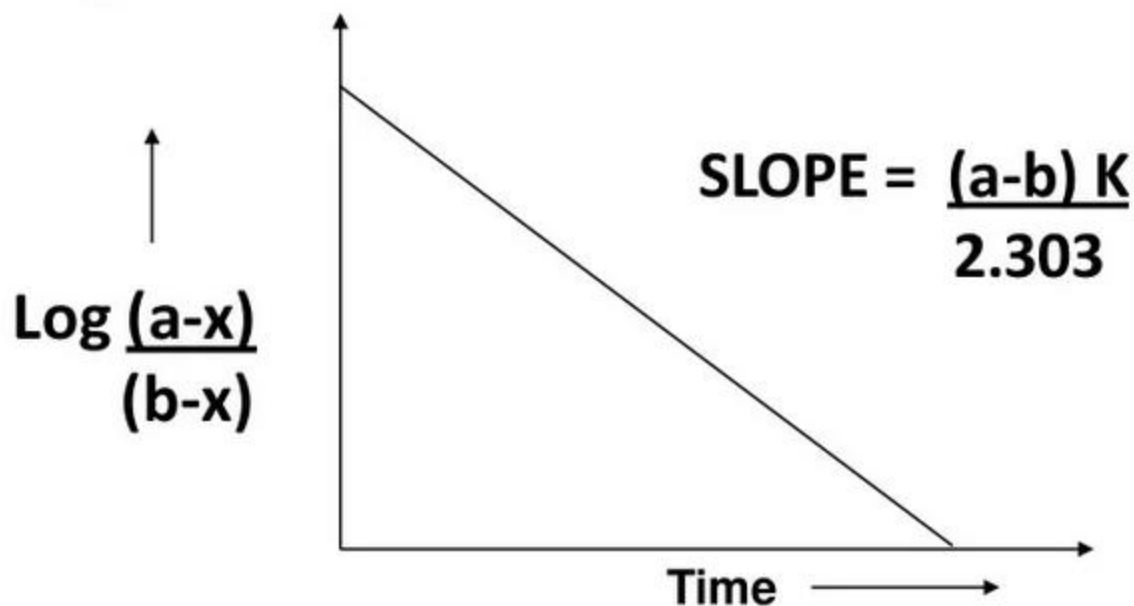
Here decrease in conc. of Y is similar to X. If conc. of X and Y at time  $t = 0$  are a and b respectively, and conc. of each substance that has reacted after time t is equal to x then conc. of X and Y remaining will be (a-x) & (b-x) respectively.

So, if second order reaction is observed then graph of

$$\log \frac{(a-x)}{(b-x)} \text{ Vs } t$$

gives **straight line** with slope  $\frac{(a-b)K}{2.303}$  and

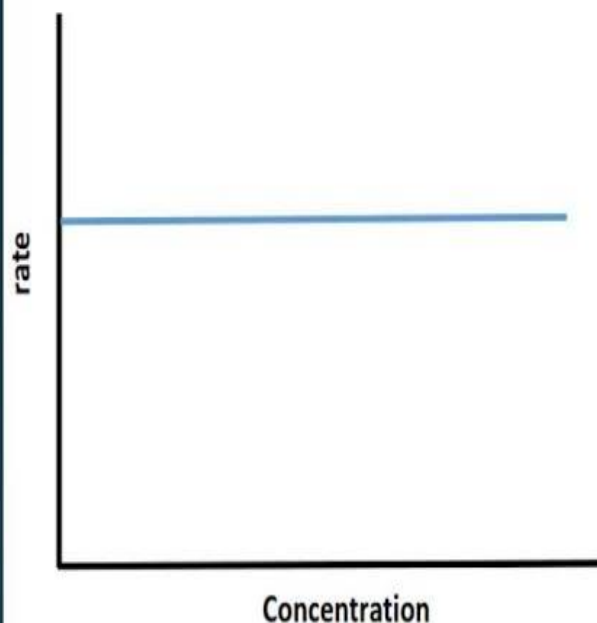
**intercept**  $\log a/b$  at  $t = 0$ .



# Graphs of reaction kinetics

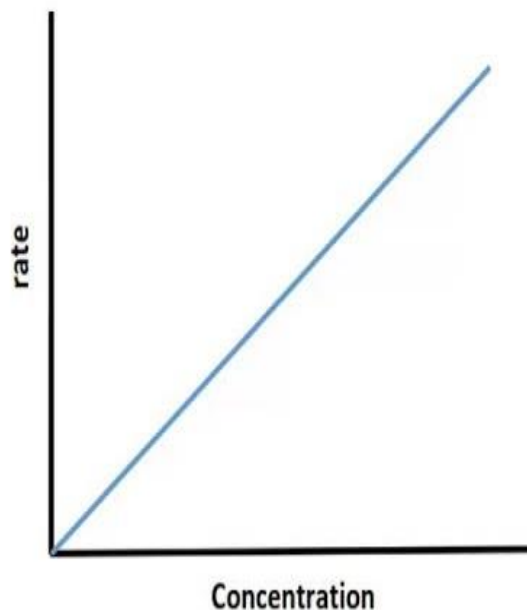
rate vs concentration (for reactant A)

Zero order



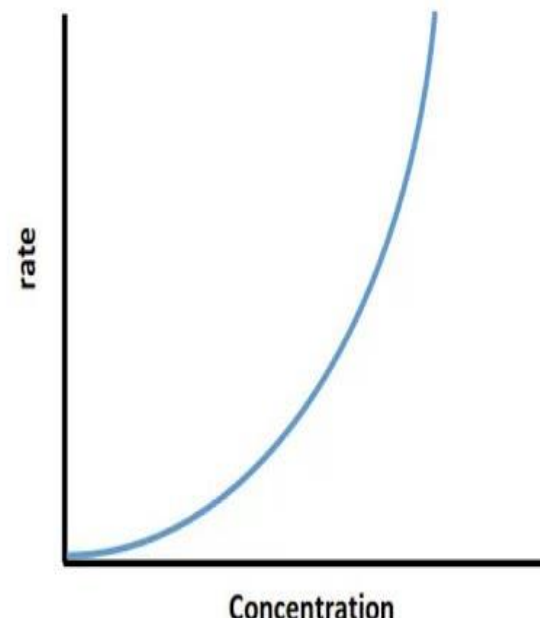
$$\text{rate} = k$$

First order



$$\text{rate} = k[A]$$

Second order



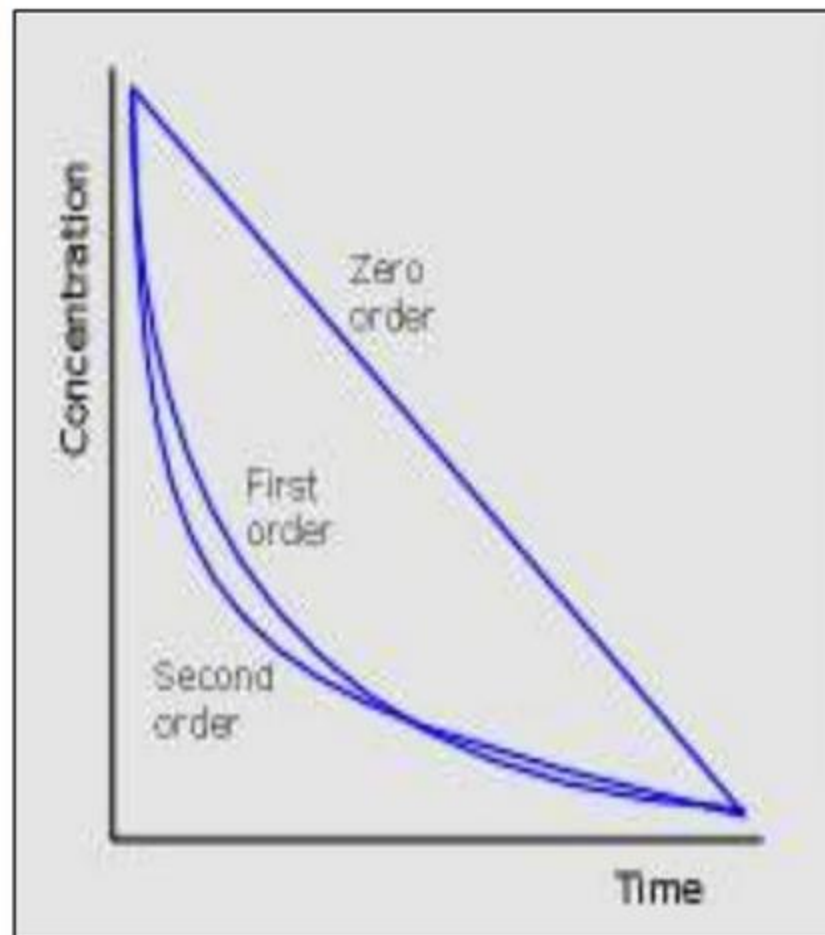
$$\text{rate} = k[A]^2$$

gradient is proportional  
to concentration

## Concentration-Time

Order	Rate Law	Equation	Half-Life
0	$\text{rate} = k$	$[A] = [A]_0 - kt$	$t_{1/2} = \frac{[A]_0}{2k}$
1	$\text{rate} = k [A]$	$\ln[A] = \ln[A]_0 - kt$	$t_{1/2} = \frac{\ln 2}{k}$
2	$\text{rate} = k [A]^2$	$\frac{1}{[A]} = \frac{1}{[A]_0} + kt$	$t_{1/2} = \frac{1}{k[A]_0}$

Order of reaction	Unit of K
Zero	$M L^{-1}Sec^{-1}$
First	$Sec^{-1}$
Second	$M^{-1}Sec^{-1}$



# ACKNOWLEDGEMENT

- Remington's pharmaceutical Science, Mack Publishing Company, 15th edition 1975, **275-283**.
- Physical; pharmacy by Alfred martin, second edition , **355-377**.
- The theory and practice of industrial pharmacy by Lachman, **760**.
- Pharmaceutics the science of dosage form design by AULTON, **119-128**
- Drug stability by Carstensen, dekker series vol: 49
- [www.rsc.org](http://www.rsc.org).