# Chemical Kinetics

Branch of physical chemistry which deals with Rates of chemical Reactions & various factors which affects the Rate of Reaction (ROR).

It also deals with mechanism of reaction

→ Rate of Reaction (ROR)
⇒ Factors affecting ROR → Temp, Pressure ...
→ Order of Reaction → I^st / II^nd / III^rd / n^th / zero
⇒ Rate Law
⇒ Molecularity of Reaction
→ Methods to determine OOR (Order of Reaction)
⇒ Mechanism of Reaction.

## Rate of Reaction (ROR)

⇒ Speed of change in concentration of reactant / Product

⇒ Change in concentration of reactant / Product per Unit time

## very Fast Reactions :-

ionic reactions complete in micro seconds
Rate cannot be measured

ex: $NaCl + AgNO_3 \longrightarrow AgCl\downarrow + NaNO_3$

$Na^+ Cl^- \quad Ag^+ NO_3^-$ very fast

There is no dissociation or formation of bond

Very slow reaction

which requires years to complete

No practical use to determine Rate

Moderate Reactions ⟶ Rate is determined

↳ Requires finite time for completion which can be measured practically

example: Molecular Reaction

$$N_2 + 3H_2 \longrightarrow 2NH_3$$

$N \equiv N$ $H-H$ $H-\underset{\displaystyle H}{\overset{\displaystyle H}{\underset{|}{\overset{|}{N}}}}-H$

Bond Break $\xrightarrow[\text{takes time}]{}$ Bond formation



There are two types of Rate :-

i) Average Rate of Reaction

ii) Instantaneous Rate of Reaction

$2A + 3B \longrightarrow 4C$

$$\text{Average ROR} = -\frac{1}{2}\frac{[\Delta A]}{[\Delta t]} = -\frac{1}{3}\frac{[\Delta B]}{[\Delta t]} = +\frac{1}{4}\frac{[\Delta C]}{[\Delta t]}$$

$3X + Y \longrightarrow 2Z$

$$\text{Average ROR} = -\frac{1}{3}\frac{[\Delta X]}{[\Delta t]} = -\frac{1}{1}\frac{[\Delta Y]}{[\Delta t]} = +\frac{1}{2}\frac{[\Delta Z]}{[\Delta t]}$$

$$\text{Rate of dissapearance of } X \text{ (ROD)} = \left|\frac{[\Delta X]}{[\Delta t]}\right|$$

$$\text{Rate of dissapearance of } Y \text{ (ROD)} = \left|\frac{[\Delta Y]}{[\Delta t]}\right|$$

$$\text{Rate of Appearance of } Z \text{ (ROA)} = \left|\frac{[\Delta Z]}{[\Delta t]}\right|$$

Units of Rate of Reaction $= \frac{\text{Conc}}{\text{time}}$ $\quad mole\, l^{-1} s^{-1}$

$= \frac{\text{Pressure}}{\text{time}}$ $\quad atm\, s^{-1}$

Q1) Write the correct expression for Average Rate of Reaction :

$$4NH_3 + 5O_2 \longrightarrow 4NO + 6H_2O$$

Ans. $ROR = -\frac{1}{4}\frac{[\Delta NH_3]}{[\Delta t]} = -\frac{1}{5}\frac{[\Delta O_2]}{[\Delta t]} = +\frac{1}{4}\frac{[\Delta NO]}{\Delta t} = +\frac{1}{6}\frac{[\Delta H_2O]}{[\Delta t]}$

Q2) $$N_2 + 3H_2 \longrightarrow 2NH_3$$

During the formation of Ammonia, 2 moles of $N_2$ dissapear in 60 s. If volume of vessel is 1L. Find i) ROR ii) ROD of $H_2$ iii) ROA of $NH_3$

Solution

i) $$ROR = -\frac{1}{1}\frac{[\Delta N_2]}{\Delta t} = \frac{\frac{2\,mole}{1L}}{60s} = \frac{1}{30}\ mol\ l^{-1}s^{-1}$$

ii) $$ROD\ of\ H_2 = -\frac{[\Delta H_2]}{\Delta t}$$

$$ROR = \frac{1}{3}\frac{[\Delta H_2]}{\Delta t}$$

$$\left|\frac{[\Delta H_2]}{[\Delta t]}\right| = 3ROR = 3\times\frac{1}{30} = \frac{1}{10}\ mol\ l^{-1}s^{-1}$$

iii) ROA of $NH_3 = \frac{[\Delta NH_3]}{[\Delta t]}$

$$ROR = \pm \frac{1}{2} \frac{[\Delta NH_3]}{[\Delta t]}$$

$$\left| \frac{[\Delta NH_3]}{[\Delta t]} \right| = 2ROR = 2 \times \frac{1}{30} = \frac{1}{15} \text{ mol } l^{-1} s^{-1}$$

Q3) $2N_2O_5 \longrightarrow 4NO_2 + O_2$

If ROA of $NO_2$ is 2mole/l sec. Find ROR & ROD of $N_2O_5$

Solution

$$ROR = -\frac{1}{2}\frac{[\Delta N_2O_5]}{[\Delta t]} = +\frac{1}{4}\frac{[\Delta NO_2]}{[\Delta t]} = \frac{1}{1}\frac{[\Delta O_2]}{[\Delta t]}$$

i) $$ROR = \pm \frac{1}{4}\frac{[\Delta NO_2]}{[\Delta t]} = \frac{1}{4} \times 2 = \frac{1}{2} \text{ mol } l^{-1} s^{-1}$$

ii) $$ROR = -\frac{1}{2}\frac{[\Delta N_2O_5]}{\Delta t}$$

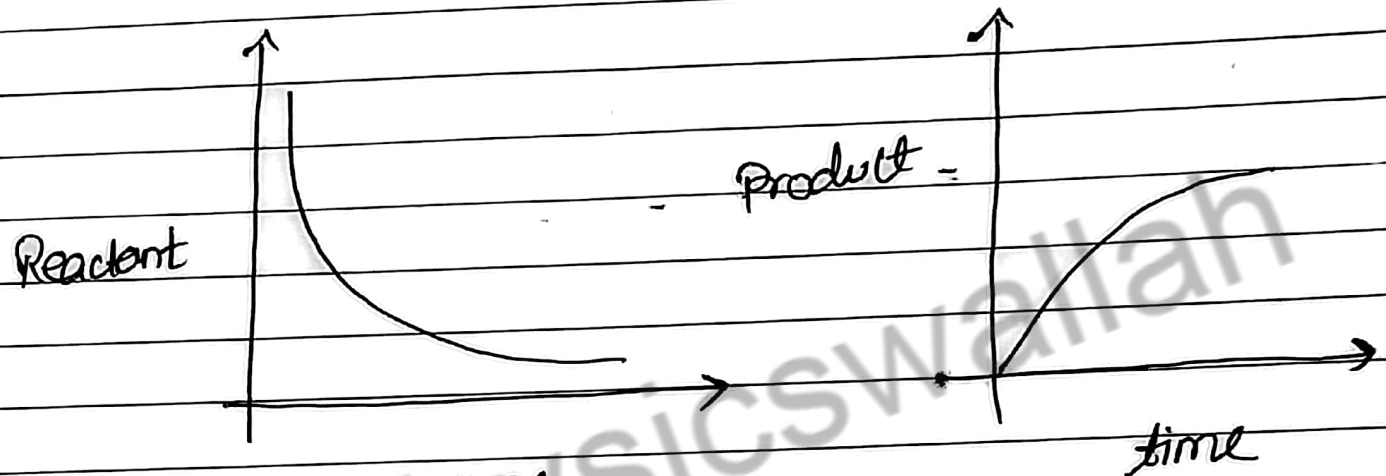
$$\left| \frac{[\Delta N_2O_5]}{[\Delta t]} \right| = 2ROR = 2 \times \frac{1}{2} = 1 \text{ mol } l^{-1} s^{-1}$$

## Instantaneous Rate of Reaction

$$2A + 3B \longrightarrow 4C$$

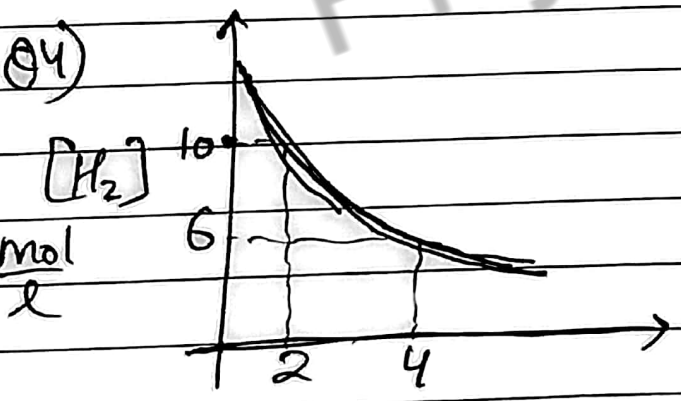
$$\text{Inst. ROR} = -\frac{1}{2}\frac{dA}{dt} = -\frac{1}{3}\frac{dB}{dt} = +\frac{1}{4}\frac{dC}{dt}$$

## Graphical Representation






Q4)




$$N_2 + 3H_2 \longrightarrow 2NH_3$$

Find i) ROR
ii) ROD of $N_2$
iii) ROA of $NH_3$

$$\frac{[\Delta H_2]}{[\Delta t]} = \frac{d[H_2]}{dt} = -\left(\frac{10-6}{4-2}\right) = \frac{4}{2} = -2 \text{ mol } l^{-1}s^{-1}$$

$$\text{ROR} = \frac{-1}{3}\frac{[\Delta H_2]}{[\Delta t]} = -\frac{1}{3} \times -2 = \frac{2}{3} \text{ mol } l^{-1}s^{-1}$$

$$ROR = -\frac{1}{1}\frac{dN_2}{dt}$$

$$\left|\frac{d[N_2]}{dt}\right| = ROR = \frac{2}{3}\ mol\ l^{-1}s^{-1}$$

$$ROR = +\frac{1}{2}\frac{d[NH_3]}{dt}$$

$$\left|\frac{d[NH_3]}{dt}\right| = 2ROR = \frac{4}{3}\ mol\ l^{-1}s^{-1}$$

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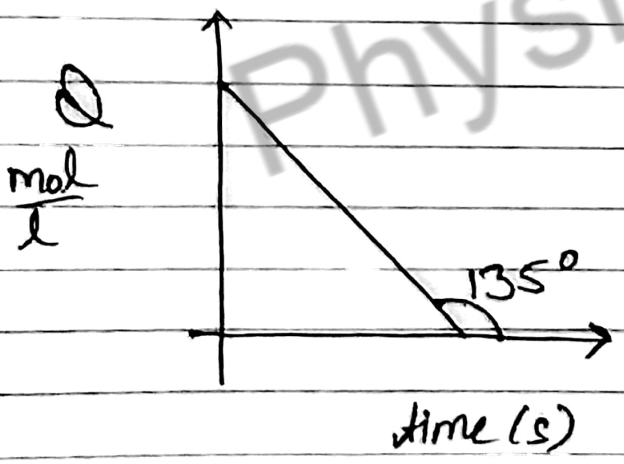
**Q5)** $2P + 3Q \longrightarrow R$

Find i) ROR
ii) ROA of R



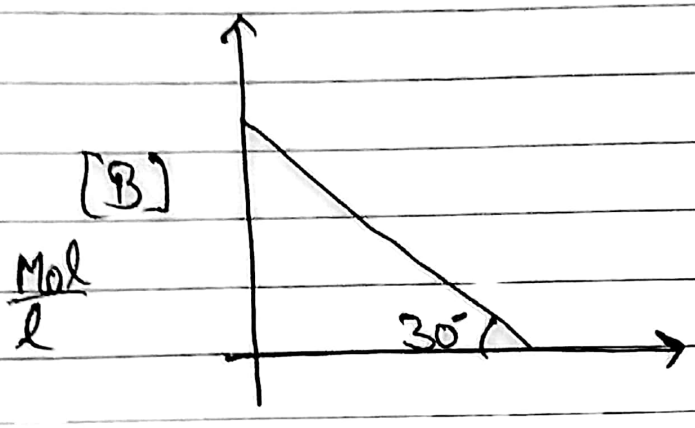

$$\frac{dQ}{dt} = \tan 135° = -1$$

i) $$ROR = -\frac{1}{3}\frac{dQ}{dt} = -\frac{1}{3} \times -1 = \frac{1}{3}\ mol\ l^{-1}s^{-1}$$

$$ROR = \frac{d[R]}{dt}$$

ii) $$\left|\frac{d[R]}{dt}\right| = ROR = \frac{1}{3}\ mol\ l^{-1}s^{-1}$$

Q6) $2A + B \longrightarrow 3C$




Find i) ROR
ii) ROA of C

$\frac{dB}{dt} = \tan 150° = -\tan 30°$

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

i) $ROR = \frac{-1}{1}\frac{d[B]}{dt} = -1 \times -\frac{1}{\sqrt{3}} = \frac{1}{\sqrt{3}} \text{ mol } l^{-1}s^{-1}$

ii) $ROR = \frac{1}{3}\frac{d[C]}{dt}$

$\left|\frac{d[C]}{dt}\right| = 3ROR = \sqrt{3} \text{ mol } l^{-1}s^{-1}$

Q7) In terms of Pressure.