# Short Answer Questions-I

## Short Answer Questions-I (PYQ)

**Q.1. Define the following:**

**Elementary step in a reaction**

**Ans. Elementary step:** The reaction which takes place in a single step is called an elementary reaction. For example,

$$N_2(g) + O_2(g) \rightarrow 2NO(g)$$

**Q.2. Rate of reaction**

**[*CBSE (AI) 2009; (F) 2010*]**

**Ans. Rate of reaction:** The rate of reaction may be defined as the decrease in concentration of reactant or increase in concentration of product per unit time.

For a hypothetical reaction, $R \rightarrow P$

$$\text{Rate of reaction} = \frac{-\Delta[R]}{\Delta t} = \frac{+\Delta[P]}{\Delta t}$$

**Q. Write two differences between 'order of reaction' and 'molecularity of reaction'.**

**[CBSE Delhi 2014]**

**Ans.** Differences between order and molecularity of reaction:

| S.No | Order | Molecularity |
|---|---|---|
| (*i*) | It is the sum of the powers of the concentration of the reactants in the rate law expression. | It is the number of reacting species taking part in an elementary reaction, which must collide simultaneously so as to result into a chemical reaction. |
| (*ii*) | It is determined experimentally. | It is a theoretical concept. |
| (*iii*) | It can be zero or a fraction. | It cannot be zero or a fraction. |
| (*iv*) | Order is applicable to elementary as well as complex reactions. | Molecularity is applicable only for elementary reactions. For complex reactions it has no meaning. |

**Q. 3.**

For a reaction: $2NH_3(g) \xrightarrow{Pt} N_2(g) + 3H_2(g)$

$$\text{Rate} = k$$

i. **Write the order and molecularity of this reaction.**

ii. **Write the unit of *k*.**

**[*CBSE South 2016*]**

**Ans.**

**i.** Zero order, bimolecular

**ii.** mol $L^{-1}$ $s^{-1}$

**Q.4. Define the following terms:**

**Q. Pseudo first order reaction**

**Ans.** A reaction which is not truely of first order but under certain conditions becomes a reaction of first order is called pseudo first order reaction, *e.g.*, acid hydrolysis of ethyl acetate.

$$CH_3COOC_2H_5 + H_2O \rightarrow H^+ CH_3COOH + C_2H_5OH$$

Rate $\propto [CH_3COOC_2H_5]$ as $H_2O$ is in excess.

**Q. Half life period of reaction ($t_{1/2}$)**

**[*CBSE Delhi 2014*]**

**Ans.** The half life ($t_{1/2}$) of a reaction is the time in which the concentration of reactant is reduced to one half of its initial concentration $[R]_0$.

For a first order reaction, $t_{1/2} = \frac{0.693}{k}$, *i.e.*, independent of $[R]_0$.

For a zero order reaction, $t_{1/2} = \frac{[R]_0}{2k}$, *i.e.*, $t_{1/2} \propto [R]_0$.

**Q.5. Answer the following questions:**

**Q.**

For a reaction $A + B \rightarrow P$, the rate law is given by,

$$r = k[A]^{1/2}[B]^2.$$

What is the order of this reaction?

**Ans.**

Order of reaction = $\frac{1}{2} + 2 = \frac{5}{2}$

**Q. A first order reaction is found to have a rate constant $k = 5.5 \times 10^{-14}\ s^{-1}$. Find the half life of the reaction.**

**[*CBSE (AI) 2013*]**

**Ans.**

Radioactive decay follows first order kinetics.

$$t_{1/2} = \frac{0.693}{k} = \frac{0.693}{5.5 \times 10^{-14}}\ s = 1.26 \times 10^{13}\ s$$

**Q.6. A reaction is of second order with respect to a reactant. How is the rate of reaction affected if the concentration of the reactant is reduced to half? What is the unit of rate constant for such a reaction?**

**[*CBSE (AI) 2011*]**

**Ans.** Consider the reaction $nR \rightarrow$ Products

As the reaction is of second order

$\therefore$ Rate, $r = k\,[R]^2$ ...(*i*)

If the concentration of the reactant reduced to half, then

$$\text{Rate, } r' = k\left[\frac{R}{2}\right]^2 \quad ...(ii)$$

Dividing equation $(ii)$ by $(i)$, we get

$$\frac{r'}{r} = \frac{k\,[R]^2}{4k\,[R]^2} = \frac{1}{4}$$

$r' = \frac{1}{4}r$, *i.e.*, rate of reaction becomes $\frac{1}{4^{\text{th}}}$ of the initial rate.

The unit of rate constant is $\mathbf{mol^{-1}\ L\ s^{-1}}$.

**Q. 7. Answer the following questions:**

**Q. Explain why $H_2$ and $O_2$ do not react at room temperature.**

**Ans.** Due to high activation energy for the reaction.

**Q. Write the rate equation for the reaction $A_2+3B_2 \rightarrow 2C$, if the overall order of the reaction is zero.**

**[*CBSE (AI) 2017*]**

**Ans.** Rate = $k[A_2]^0[B_2]^0$ or Rate = $k$

**Q.8. Show that in a first order reaction, time required for completion of 99.9% is 10 times that of half-life ($t_{1/2}$) of the reaction.**

**[*CBSE (F) 2016*]**

**Ans.**

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

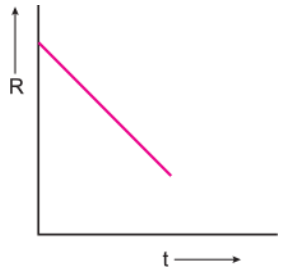
$$\frac{t_{99.9\%}}{t_{50\%}} = \frac{\frac{2.303}{k}\log\frac{100}{100\ -\ 99.9}}{\frac{2.303}{k}\log\frac{100}{100\ -50}} = \frac{\log\frac{100}{0.1}}{\log\frac{100}{50}}$$

$$= \frac{\log 10^3}{\log 2} = \frac{3\log 10}{0.3010}$$

$$\frac{t_{99.9\%}}{t_{50\%}} = \frac{30}{3.01} \simeq 10$$

$$t_{99.9\%} = 10t_{50\%}$$

**Q.9. For a chemical reaction $R \rightarrow P$, the variation in the concentration ($R$) vs. time ($t$) plot is given as**




i. **Predict the order of the reaction.**
ii. **What is the slope of the curve?**

**[*CBSE (AI) 2014*]**

**Ans.**

i. Order of the reaction is zero.

ii. Slope = $\frac{d[R]}{dt} = -k$

**Q.10. What do you understand by the rate law and rate constant of a reaction? Identify the order of a reaction if the units of its rate constant are:**

**[*CBSE (AI) 2011*]**

i. **$L^{-1}$ mol $s^{-1}$**
ii. **L $mol^{-1}$ $s^{-1}$.**

**Ans.** An experimentally determined expression which relates the rate of reaction with the concentration of reactants is called rate law while the rate of reaction when concentration of each reactant is unity in a rate law expression is called rate constant.

Comparing power of mole in $L^{-1}$ mol $s^{-1}$ and $(mol\ L^{-1})^{1-n}$ $s^{-1}$,
We get

$$1 = l - n \quad \Rightarrow n = 0 \textit{ i.e.}, \text{ zero order reaction}$$

Again comparing power of mole in L $mol^{-1}s^{-1}$ and (molL–1)1–ns–1, we get

$$-1 = 1 - n \Rightarrow n = 2, \textit{ i.e.}, \text{ second order reaction}$$

**Q.11. The rate constant for a first order reaction is 60 $s^{-1}$. How much time will it take to reduce the initial concentration of the reactant to $\frac{1}{10}$ th of its initial value?**

**[*CBSE (F) 2013*]**

**Ans.**

$$t = \frac{2.303}{k} \log \frac{[R]_0}{[R]} \quad \text{as} \quad [R] = \frac{[R]_0}{10}$$

$$\therefore \quad t = \frac{2.303}{k} \log \frac{[R]_0}{\frac{[R]_0}{10}} = \frac{2.303}{60} \times \log 10 = \frac{2.303}{60} \times 1 = 3.838 \times 10^{-2} s$$

**Q.12. The rate constant for a zero order reaction is 0.0030 mol $L^{-1}$ $s^{-1}$. How long will it take for the initial concentration of the reactant to fall from 0.10 M to 0.075 M?**

**[*CBSE (F) 2010*]**

**Ans.**

Given: $[R_0] = 0.10$ M $\qquad [R] = 0.075$ M

$k = 0.0030$ mol $L^{-1}$ $s^{-1}$, $t = ?$

We know that $k = \frac{[R_0]-[R]}{t}$

or $\qquad t = \frac{[R_0]-[R]}{k} = \frac{0.10 - 0.075}{0.0030} = 8.33\ s.$

## Short Answer Questions-I (OIQ)

**Q.1. Why does the rate of any reaction generally decrease during the course of the reaction?**

**[*NCERT Exemplar*]**

**Ans.** The rate of reaction depends on the concentration of reactants. As the reaction progresses, reactants start getting converted to products so the concentration of reactants decreases hence the rate of reaction decreases.

**Q.2. Why is molecularity applicable only for elementary reactions and order is applicable for elementary as well as complex reactions?**

**[*NCERT Exemplar*]**

**Ans.** A complex reaction proceeds through several elementary reactions. Number of molecules involved in each elementary reaction may be different, *i.e.*, the molecularity of each step may be different. Therefore, discussion of molecularity of overall complex reaction is meaningless. On the other hand, order of a complex reaction is determined

by the slowest step in its mechanism and is not meaningless even in the case of complex reactions.

**Q.3. For a zero order reaction will the molecularity be equal to zero? Explain.**

**[*NCERT Exemplar*]**

**Ans.** No, the molecularity can never be equal to zero or a fractional number. Molecularity is the number of molecules involved in each elementary reaction which may be different, *i.e.*, the molecularity of each step may be different.

**Q.4. Differentiate between rate of reaction and reaction rate constant.**

**Ans.**

| S. No. | Rate of Reaction | Reaction Rate Constant |
|---|---|---|
| (*i*) | Rate of reaction is the change in concentration of a reactant or product in a unit interval of time. | It is the rate of reaction when the molar concentration of each of the reactants is unity. |
| (*ii*) | The rate of reaction at any instant of time depends upon the molar concentrations of the reactants at that time. | The rate constant does not depend upon the concentrations of the reactants. |
| (*iii*) | Its units are always mol litre$^{-1}$ time$^{-1}$. | Its units depend upon the order of reaction. |

**Q.5. The form of the rate law for a reaction is expressed as: rate** = $k[Cl_2][NO]^2$

**Find out the orders of the reaction with respect to $Cl_2$ and with respect to NO and also the overall order of this reaction.**

**Ans.** Order with respect to $Cl_2$ = 1, Order with respect to NO = 2,

Overall order = 1 + 2 = 3

**Q.6. Calculate the overall order of a reaction which has the rate expression,**

i. **Rate = $k[A]^{1/2}[B]^{3/2}$**
ii. **Rate = $k[A]^{3/2}[B]^{-1}$**

**Ans.**

i. Order = $\frac{1}{2} + \frac{3}{2} = 2$, *i.e.*, second order.

ii. Order = $\frac{3}{2} + (-1) = \frac{1}{2}$, *i.e.*, half order.

**Q.7. For a reaction: *A* + $H_2O$ → *B*, Rate ∝ [*A*].**

**What is its (*i*) molecularity (*ii*) order of reaction?**

**Ans.**

**i.** Pseudo unimolecular
**ii.** Order = 1.

**Q.8. Answer the following questions:**

**Q. The conversion of the molecule *X* to *Y* follows second order kinetics. If the concentration X is increased to three times, how will it affect the rate of formation of Y?**

**Ans.**

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

$$r_1 = k[X]^2 \qquad \ldots(i)$$

$$r_2 = k[3X]^2 \qquad \ldots(ii)$$

Dividing $(ii)$ by $(i)$,

$$\frac{r_2}{r_1} = \frac{9k\,[X]^2}{k\,[X]^2} \quad \text{or} \quad r_2 = 9r_1$$

Thus, rate of formation of $Y$ will increase by nine times.

**Q. The specific reaction rate of a reaction is $6.2 \times 10^{-3}$ mol $L^{-1}$ $s^{-1}$. What is the order of reaction?**

**Ans.** Comparing the unit of *k*, with the general unit $(\text{mol L}^{-1})^{1-n}\ \text{s}^{-1}$, we get

$$\text{mol}^{1-n} = \text{mol}^1$$

$$1 - n = 1$$

⇒ $n = 0$, *i.e.*, zero order reaction.

**Q.9. The rate law for the reaction: Ester + $H^+$ → Acid + Alcohol is:**

$$\frac{dx}{dt} = k\,[\text{Ester}]\,[H^+]^0$$

**What would be the effect on the rate if (*i*) concentration of the ester is doubled? (*ii*) concentration of $H^+$ is doubled?**

**Ans.** (*i*) The rate of reaction will be doubled. (*ii*) No effect on rate.

**Q.10. Derive an expression to calculate time required for completion of zero order reaction.**

**[*NCERT Exemplar*]**

**Ans.**

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

For completion, $[R] = 0$

$$\therefore \quad t = \frac{[R]_0}{k}$$

**Q.11. The rate constant for a reaction of zero order in *A* is 0.0030 mol $L^{-1}$ $s^{-1}$. How long will it take for the initial concentration of *A* to fall from 0.10 M to 0.075 M?**

**Ans.**

$$k = 0.0030 \text{ mol } L^{-1}s^{-1},\ [R]_0 = 0.10 \text{ M},\ [R] = 0.075 \text{ M}$$

We know that

$$[R] = -kt + [R]_0$$

$$0.075 = -0.0030t + 0.10$$

$$\Rightarrow \qquad 3t = 100 - 75 \quad \Rightarrow \quad t = \mathbf{8.33 \text{ seconds}}$$

**Q.12. The following data were obtained during the first order thermal decomposition of $SO_2Cl_2$ at a constant volume:**

$$\mathbf{SO_2Cl_2(\mathit{g}) \rightarrow SO_2(\mathit{g}) + Cl_2(\mathit{g})}$$

| Experiment | Time/second$^{-1}$ | Total pressure/atm |
|---|---|---|
| 1 | 0 | 0.4 |
| 2 | 100 | 0.7 |

**Calculate the rate constant.**

**(Given: log 4 = 0.6021, log 2 = 0.3010)**

**[*HOTS*]**

**Ans.**

$$k = \frac{2.303}{t} \log \frac{P_0}{2P_0 - P_t}$$

Here, $P_0 = 0.4$ atm, $t = 100$ s, $P_t = 0.7$ atm

$$\therefore \quad k = \frac{2.303}{100} \log \frac{0.4}{2 \times 0.4 - 0.7}$$

$$= \frac{2.303}{100} \log \frac{0.4}{0.1} = \frac{2.303}{100} \log 4 = \frac{2.303}{100} \times 0.6021$$

$$k = \mathbf{1.386 \times 10^{-2}\ s^{-1}}$$

**Q.13. 87.5% of the substance disintegrated in 45 minutes (first order reaction). What is its half-life?**

**Ans.**

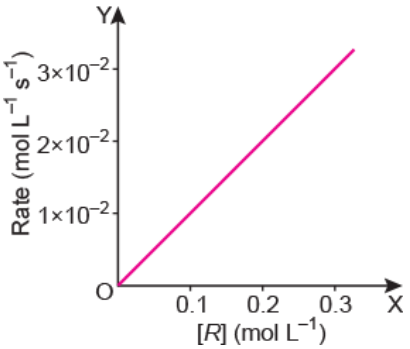
$\left(\frac{1}{2}\right)^n = \frac{12.5}{100}$ because 87.5% has disintegrated, amount left is 12.5%.

$$\left(\frac{1}{2}\right)^n = \left(\frac{1}{8}\right) \quad \Rightarrow \quad \left(\frac{1}{2}\right)^n = \left(\frac{1}{2}\right)^3$$

Number of half lives = 3

$$t_{1/2} = \frac{45}{3} = \mathbf{15\ minutes}$$

**Q.14. The rate for the reaction** R→P **is rate =** ***k*****[*R*]. It has been shown graphically below. What is rate constant for the reaction?**




**Ans.**

From the graph

**Case I:** Rate = $k[A]$

$$1 \times 10^{-2} \text{ mol L}^{-1} \text{ s}^{-1} = k\ (0.1 \text{ mol L}^{-1})$$

$$\therefore \quad k = \frac{1 \times 10^{-2} \text{ mol } L^{-1}s^{-1}}{0.1 \text{ mol } L^{-1}} = 0.1 \text{ s}^{-1}$$

**Case II:**

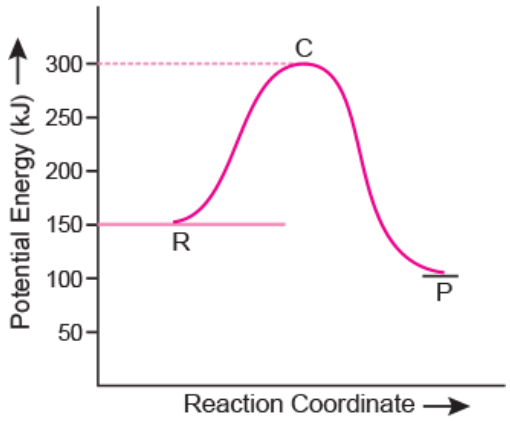
$$3 \times 10^{-2} \text{ mol L}^{-1}\text{s}^{-1} = k\ (0.3 \text{ mol L}^{-1})$$

$$k = \frac{3 \times 10^{-2} \text{ mol } L^{-1}s^{-1}}{0.3 \text{ mol } L^{-1}} = 0.1 \text{ s}^{-1}$$

Hence, $k = 0.1 \text{ s}^{-1}$

**Q.15. Answer the following questions on the basis of the given plot of potential energy vs reaction coordinate:**

i. **What is the threshold energy for the reaction?**
ii. **What is the activation energy for forward reaction?**
iii. **What is the activation energy for backward reaction?**
iv. **What is enthalpy change for the forward reaction?**




**Ans.**

i. Threshold energy for the reaction = 300 kJ $mol^{-1}$

ii. Activation energy for the forward reaction = 300 – 150
= 150 kJ $mol^{-1}$

iii. Activation energy for the backward reaction = 300 – 100
= 200 kJ $mol^{-1}$

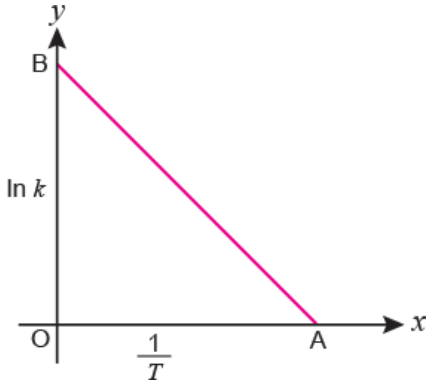
iv. Enthalpy change for the forward reaction $\Delta_r H$ = 100 – 150
= – 50 kJ $mol^{-1}$

**Q.16. A graph between ln *k* and $\frac{1}{T}$ for a reaction is given. Here *k* is rate constant and *T* is temperature in Kelvin.**

**[*HOTS*]**

**If *OA* = *a* and *OB* = *b*, answer the following:**

i. **What is the activation energy ($E_a$) of the reaction?**
ii. **What is the frequency factor (*A*) for the reaction?**



**Ans.**

According to Arrhenius equation, $\ln k = -\frac{E_a}{RT} + \ln A$

i. Slope $= -\frac{OB}{OA} = -\frac{b}{a} = -\frac{E_a}{R}$ or $E_a = \frac{b}{a} R$

ii. Intercept on $y$-axis $= OB = b = \ln A$ or $A = e^b$

**Q.17. Rate constant *k* for first order reaction has been found to be $2.54 \times 10^{-3}\ s^{-1}$. Calculate its three-fourth life.**

**[*CBSE Sample Paper 2013*]**

**Ans.**

$$t = \frac{2.303}{k} \log \frac{[R]_0}{[R]} \quad \ldots(i)$$

$$k = 2.54 \times 10^{-3} s^{-1}; [R] = \frac{[R]_0}{4}$$

Substituting these values in equation (i), we get

$$t_{3/4} = \frac{2.303}{2.54 \times 10^{-3}} \log \frac{[R]_0}{\frac{[R]_0}{4}} = 0.9066 \times 10^3 \log 4$$

$t_{3/4} = 0.9066 \times 10^3 \times 0.6021\ s = \mathbf{5.46 \times 10^2\ s}$

**Q.18. After 24 hrs, only 0.125 gm out of the initial quantity of 1 gm of a radioactive isotope remains behind. What is its half life period?**

**[*CBSE Sample Paper 2017*]**

**Ans.**

Here, $[R]_0 = 1$ g, $[R] = 0.125$ g, $t = 24$ h

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

$$k = \frac{2.303}{24} \log \frac{1}{0.125}$$

$$k = \frac{2.303}{24} \log 8$$

$$k = \frac{2.303}{24} \times 0.9031$$

$$k = 0.0866\ h^{-1}$$

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

$$t_{1/2} = \frac{0.693}{0.0866\ h^{-1}} \text{ or } t_{1/2} = 8\ h$$

**Q.19. A first order gas reaction $A_2B_2(g) \rightarrow 2A(g) + 2B(g)$ at the temperature 400°C has the rate constant $K = 2.0 \times 10^{-4}\ s^{-1}$. What percentage of $A_2B_2$ is decomposed on heating for 900 seconds.**

**[*CBSE Sample Paper 2013*]**

**Ans.**

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

$$2.0 \times 10^{-4} s^{-1} = \frac{2.303}{900} \log \frac{[R]_0}{[R]}$$

$$\log \frac{[R]_0}{[R]} = \frac{2.0 \times 10^{-4} \times 900}{2.303} = 0.0781$$

$$\log \frac{[R]}{[R]_0} = -\ 0.0781$$

$$\frac{[R]}{[R]_0} = \text{Antilog } \bar{1}.9219$$

$$\frac{[R]}{[R]_0} = 0.835$$

$[R] = 0.835\ [R]_0$

If $[R]_0 = 100$, then

$[R] = 83.5$

$R]_0 - [R] = 100 - 83.5 = 16.5$, *i.e.*, 16.5% of initial concentration has changed into products.

**Q.20. Consider the decomposition of hydrogen peroxide in alkaline medium which is catalysed by iodide ions.**

$$2H_2O_2 \xrightarrow{OH^-} 2H_2O + O_2$$

This reaction takes place in two steps as given below:

Step-I $H_2O_2 + I^- \rightarrow H_2O + IO^-$ *(slow)*

Step-II $H_2O_2 + IO^- \rightarrow H_2O + I^- + O_2$ *(fast)*

i. Write the rate law expression and determine the order of reaction w.r.t. $H_2O_2$.

ii. What is the molecularity of each individual step?

**Ans.**

i. Rate = $k\,[H_2O_2]^1\,[I^-]^1$

Order of reaction w.r.t $H_2O_2$ = 1

ii. Molecularity of step I = 2 and step II = 2.