

CONCEPT 7 — 3.3.2

First Order Reactions

The Kinetic Dashboard: Form, Function, and Execution for Competitive Exams

KINETIC DASHBOARD: GLOBAL FORM EQUATIONS

Differential Form

Use: Instantaneous rates

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

Exponential Form

Use: Concentration over time

$$[R] = [R]_0 e^{-kt}$$

Linear Log Form

Use: Natural log graphing

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

Base-10 Form

Use: Numerical calculations

$$k = (2.303/t) \log([R]_0/[R])$$

Gas Phase Form

Use: Partial pressure systems

$$p_A = 2p_i - p_t$$



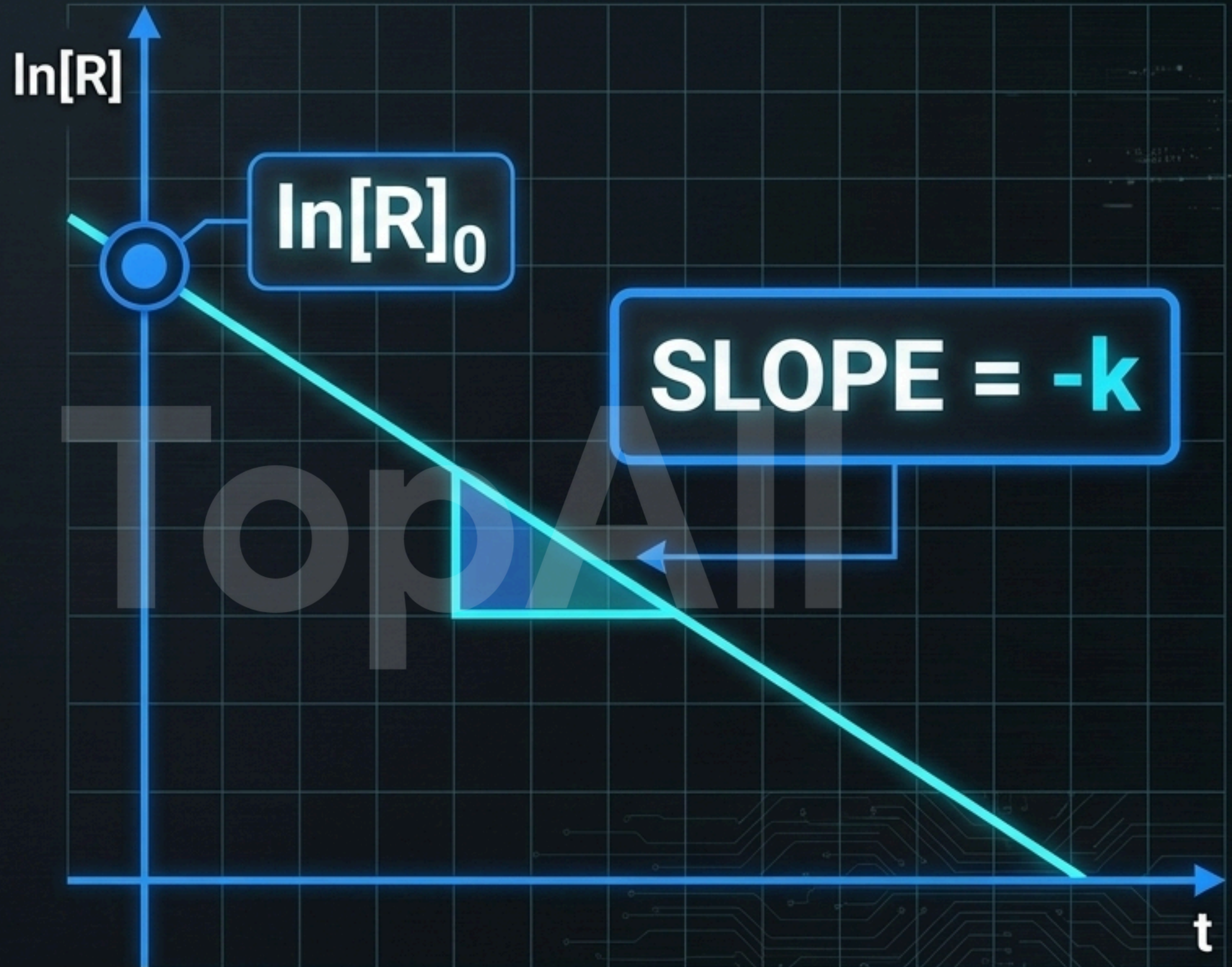
KINETIC DASHBOARD: LINEAR LOG MAPPING

THE MAPPING

$$y = mx + c$$

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

A straight line for natural log denotes first-order kinetics.





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KINETIC DASHBOARD: THE BASE-10 SHIFT

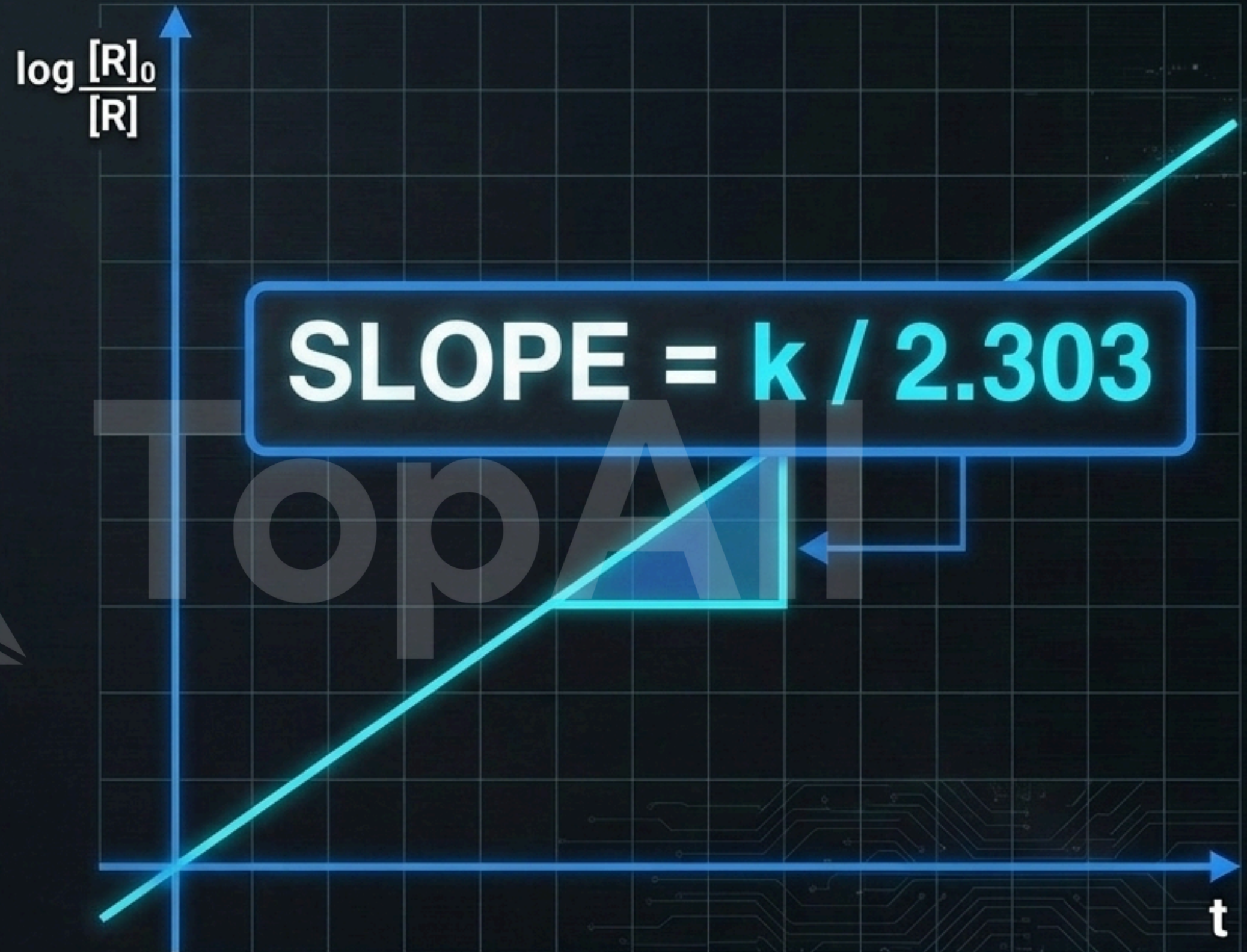


THE BASE-10 SHIFT

$$y = mx + c$$

$$\log\left(\frac{[R]_0}{[R]}\right) = \frac{k}{2.303}t + 0$$

Why the origin? At $t=0$, $[R] = [R]_0$.
Therefore, $\log(1) = 0$.



KINETIC DASHBOARD: RATE CONSTANT EXECUTION

REACTION: $\text{N}_2\text{O}_5 \rightarrow 2\text{NO}_2 + \frac{1}{2}\text{O}_2$ (AT 318 K)

$t_1 = 0$ min



$[\text{R}]_1 = 1.24 \times 10^{-2} \text{ mol L}^{-1}$

$t_2 = 60$ min



$[\text{R}]_2 = 0.20 \times 10^{-2} \text{ mol L}^{-1}$

EXECUTION PIPELINE

$$k = \left[\frac{2.303}{t_2 - t_1} \right] \log \left(\frac{[\text{R}]_1}{[\text{R}]_2} \right)$$

$$k = \left[\frac{2.303}{60} \right] \log \left(\frac{1.24 \times 10^{-2}}{0.20 \times 10^{-2}} \right)$$

$$k = \left[\frac{2.303}{60} \right] \log(6.2)$$

$$k = 0.0304 \text{ min}^{-1}$$

KINETIC DASHBOARD: STATE TRANSITION MATRIX

Standard First-Order Gas Phase ($A \rightarrow B + C$)

	A(g)	→	B(g)	+	C(g)
t = 0	p_i		0		0
time t	$(p_i - x)$		x		x

DERIVATION PATHWAY

$$\text{Total Pressure } (p_t) = (p_i - x) + x_x = p_i + x$$
$$\text{Therefore, } x = p_t - p_i$$

$$\text{Active Reactant Pressure: } p_A = p_i - x = 2p_i - p_t$$

KINETIC DASHBOARD: LN vs. LOG₁₀ TRAP & EXECUTION




$$k = \frac{1}{t} \log_{10} \left(\frac{[R]_0}{[R]} \right)$$

FATAL ERROR: Mixing up ln and log₁₀ geometries without applying the conversion factor.


$$k = \frac{2.303}{t} \log_{10} \left(\frac{[R]_0}{[R]} \right)$$

JEE STANDARD: Always multiply by 2.303 when extracting rate constants from base-10 log data.

KINETIC DASHBOARD: SYSTEM DIAGNOSTIC



For a first-order reaction, a plot of $\log([R]_0/[R])$ versus time is a straight line. What is the value of its slope?

[A] k

[B] $-k$

[C] $k / 2.303$ ✓

[D] $-k / 2.303$

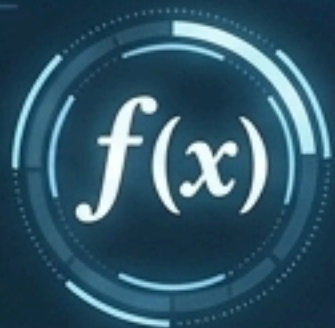


SYSTEM READOUT

Answer: C.

Justification: Because the Y-axis is plotted in base-10 log rather than natural ln, the slope must account for the 2.303 conversion factor. Since $[R]_0/[R]$ is an inverted ratio, the slope is positive.

KINETIC DASHBOARD: FINAL SYNTHESIS



Dependence

First-order rates depend strictly on the first power of concentration.



Graphical Hallmark

A straight descending line for $\ln[R]$ vs t (Slope = $-k$).



The Log Factor

Always apply the 2.303 multiplier when using base-10 log to calculate k .



Stoichiometric Pressure

In gas-phase $A \rightarrow B + C$, the active partial pressure is $p_A = 2p_i - p_t$.



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