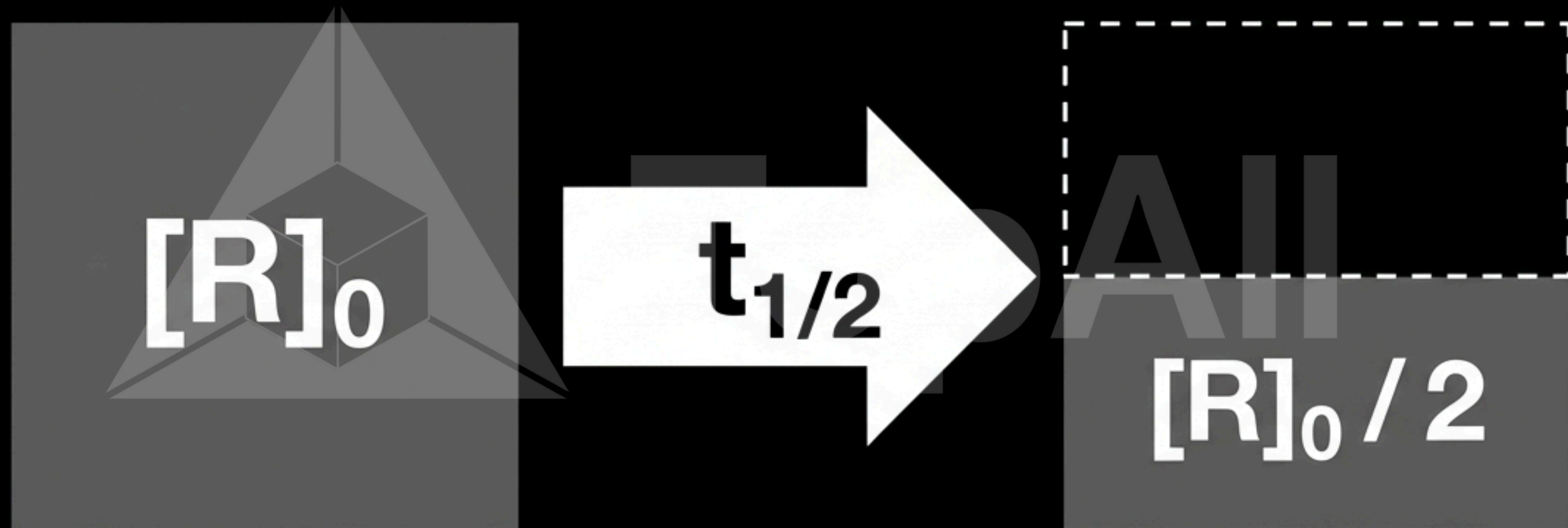


Half-Life of a Reaction

The ultimate conceptual blueprint for $t_{1/2}$ calculations, comparisons, and exam trap avoidance.

The time for concentration to fall to *half* its initial value.



$t_{1/2}$ is the universal variable for half-life, regardless of the reaction's order.

[ZERO_ORDER]

$$k = ([R]_0 - [R])/t$$

$$\text{At } t_{1/2}, [R] = [R]_0 / 2$$

$$t_{1/2} = \underline{[R]_0} / 2k$$

[FIRST_ORDER]

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

$$\text{At } t_{1/2}, [R] = [R]_0 / 2 \rightarrow \log(2) = 0.301$$

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

Notice: $[R]_0$ is completely absent.



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$$E=mc^2$$



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The Dependency Matrix (Table 3.4 Rebuilt)

Order	Half-life formula ($t_{1/2}$)	Depends on initial conc. $[R]_0$?
Zero	$[R]_0 / 2k$	YES. (Directly proportional: $t_{1/2} \propto [R]_0$)
First	$0.693 / k$	NO. (It is a constant, regardless of starting amount)

Citation: Based on mathematical features of integrated rate laws summary table.

The Exam Cheat Code (From Example 3.8)

Question: Prove time for 99.9% completion of a first-order reaction is 10x its half-life.

Calculate $t_{99.9\%}$

$$[R] = [R]_0 - 0.999[R]_0 = 0.001[R]_0$$

$$t_{99.9\%} = (2.303/k) \log(10^3) \rightarrow 6.909/k$$

Recall $t_{1/2}$

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

} ÷ Yields ≈ 10

Memorize this: $t_{99.9\%} = 10 \times t_{1/2}$. (Saves 3 minutes in the exam).



JEE/NEET TRAP ALERT



Panicking under time limits and blindly using
 $t_{1/2} = 0.693/k$ for EVERY reaction.

~~Zero Order Reaction $\rightarrow t_{1/2} = 0.693/k$~~

DEATH TRAP!



$0.693/k$ is an **exclusive** property of **FIRST ORDER** reactions only. If the question states "Zero Order", you must factor in the initial concentration: $[R]_0 / 2k$.

A first-order reaction has a half-life of 20 seconds. If the initial concentration of the reactant is artificially tripled, what is the new half-life?

[A] 6.66 seconds

 **[B]** 20 seconds

[C] 60 seconds

[D] Cannot be determined

Explanation

First-order $t_{1/2} = 0.693/k$. The formula contains no $[R]_0$ term. Therefore, half-life remains completely unaffected by changes in starting concentration.

Key Takeaways: The Golden Rules of $t_{1/2}$

$$t_{1/2} \propto [R]_0$$

Half-life scales with **starting material**. More initial concentration = longer half-life.

$$t_{1/2} = \text{CONSTANT}$$

Half-life is **locked** to the **rate constant** (k). Initial concentration is irrelevant.

Lock these dependencies in your memory to solve conceptual MCQs in under 10 seconds.



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