Integrated Rate Laws

Method #2: Go straight! Different orders require different plots to generate straight lines.

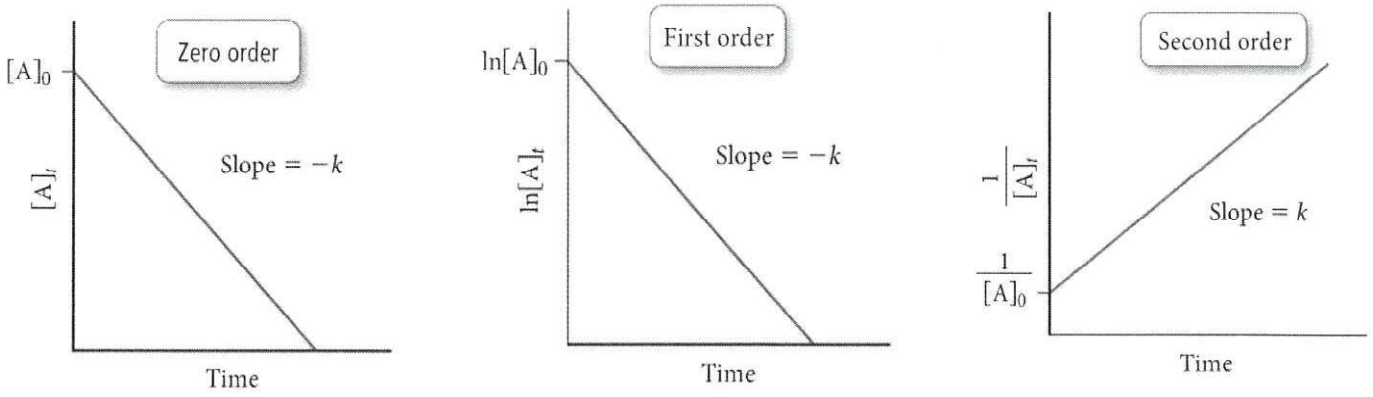
To create the needed graphs, set time as your x-axis, and graph three different y-axes (in alphabetical order!)

- **C:** Concentration of the reactant, [A] vs time
- **L:** Natural log of the concentration, ln[A] vs time
- **R:** Reciprocal of the concentration, 1/[A] vs time

Alpha Order

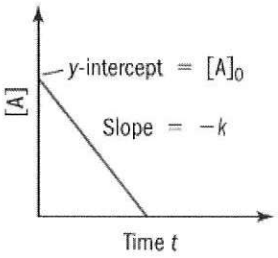
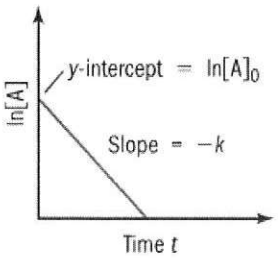
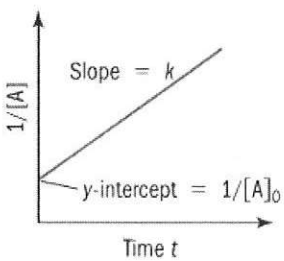
[A]	ln [A]	1/[A]
Concentr.	Ln	Reciprocal
0th	1st	2nd

The graph which is **most linear** is the one you want!



Note: for each rate order, the absolute value of the slope is equal to the rate constant → IF you pick the correct graph!

$$k = |slope|$$

Order	Rate Law	Units of k	Integrated Rate Law	Straight-Line Plot	Half-Life Expression
0	Rate = $k[A]^0$	$M \cdot s^{-1}$	not on F.C. $[A]_t = -kt + [A]_0$ $y = mx + b$ (slope-intercept form)		$t_{1/2} = \frac{[A]_0}{2k} = \frac{1}{k}\frac{[A]_0}{2}$ not AP tested
1	Rate = $k[A]^1$	s^{-1}	$\ln[A]_t = -kt + \ln[A]_0$ on F.C. $\ln\frac{[A]_t}{[A]_0} = -kt$		AP tested! $t_{1/2} = \frac{0.693}{k} = \frac{1}{k}(0.693)$ on F.C. ☺
2	Rate = $k[A]^2$	$M^{-1} \cdot s^{-1}$	on F.C. $\frac{1}{[A]_t} = kt + \frac{1}{[A]_0}$		$t_{1/2} = \frac{1}{k[A]_0} = \frac{1}{k}\frac{1}{[A]_0}$ not AP tested

Units for the Rate Constant (k): different depending of your overall reaction order! The AP Test loves to ask you about the correct units for k given a specific rate law.

Remember: the units of rate are always M/time (often, M/sec; be sure to notice which unit of time is used).

To determine the unit of k for a given rate law, you can use dimensional analysis (yum!) or the following handy equation:

If **p = overall rate order** (Sum of the rate order of each reactant), then:

$$\text{Units for k} = M^{1-p}\, time^{-1}$$

Now you try! Determine the units of k for each of the following rate laws.

1. Rate = k[NO_2], overall order of reaction: 1 units of k = 1/time ($time^{-1}$)
2. Rate = k[H_2][NO]^2, overall order of reaction: 3 units of k = $\frac{1}{M^2 time}$ ($M^{-2}\,time^{-1}$)
3. Rate = k[H_2O]^0, overall order of reaction: 0 units of k = M/time (M $time^{-1}$)
4. Rate = k[O_3]^2, overall order of reaction: 2 units of k = $\frac{1}{M time}$ ($M^{-1}\,time^{-1}$)

Multiple Choice Practice!

Questions 1-3 refer to the following reaction and rate laws. A + B → C

(A) Rate = k [A]
(B) Rate = k [A]^2
(C) Rate = k [A][B]^2
(D) Rate = k [A]^2[B]
(E) Rate = k [B]

1. Which represents a reaction that is zero order with respect to reactant A? E
2. Which represents a reaction that is second order with respect to reactant A and is third order overall? D
3. Which represents a reaction that is zero order with respect to reactant B and is second order overall? B
4. For the reaction whose rate law expression is rate = k[X]^2, a plot of which of the following is a straight line? (2nd order)
   a) [X] versus time 0th
   b) ~~[X] versus 1/time~~ never
   c) 1/[X] versus time
   d) ln [X] versus time 1st
   e) ~~ln [X] versus 1/time~~ never
5. Each of the following factors can affect the rate of a chemical reaction EXCEPT
   a) increasing temperature ↑T = ↑k
   b) decreasing reactant concentration ↓[reactants] = ↓rate
   c) adding a catalyst by definition
   d) removing products
   e) breaking up solid reactants ↑ surface area = ↑rate