

## 9.4: First-Order Reactions Show an Exponential Decay of Reactant Concentration with Time

A first order rate law would take the form

$$\frac{d[A]}{dt} = k[A]$$

Again, separating the variables by placing all of the concentration terms on the left and all of the time terms on the right yields

$$\frac{d[A]}{[A]} = -k dt$$

This expression is also easily integrated as before

$$\int_{[A]=0}^{[A]} \frac{d[A]}{[A]} = -k \int_{t=0}^{t=t} dt$$

Noting that

$$\frac{dx}{x} = d(\ln x)$$

The form of the integrated rate law becomes

$$\ln[A] - \ln[A]_0 = kt$$

or

$$\ln[A] = \ln[A]_0 - kt \quad (9.4.1)$$

This form implies that a plot of the natural logarithm of the concentration is a linear function of the time. And so a plot of  $\ln[A]$  as a function of time should produce a linear plot, the slope of which is  $-k$ , and the intercept of which is  $\ln[A]_0$ .

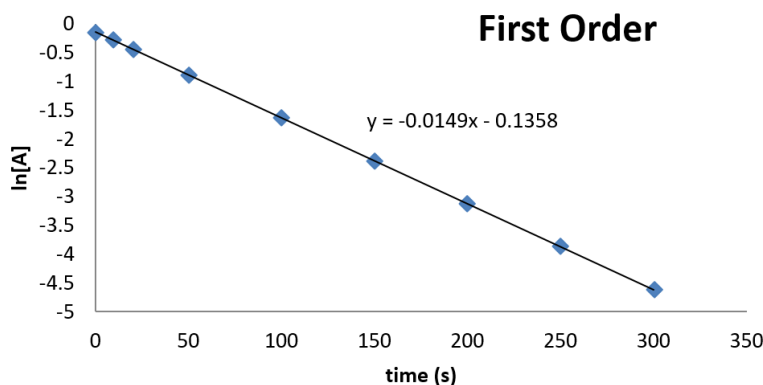
### ✓ Example 9.4.1:

Consider the following kinetic data. Use a graph to demonstrate that the data are consistent with first order kinetics. Also, if the data are first order, determine the value of the rate constant for the reaction.

Time (s)	0	10	20	50	100	150	200	250	300
[A] (M)	0.873	0.752	0.648	0.414	0.196	0.093	0.044	0.021	0.010

### Solution

The plot looks as follows:



From this plot, it can be seen that the rate constant is  $0.0149 \text{ s}^{-1}$ . The concentration at time  $t = 0$  can also be inferred from the intercept.

It should also be noted that the integrated rate law (Equation 9.4.1) can be expressed in exponential form:

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

Because of this functional form, 1<sup>st</sup> order kinetics are sometimes referred to as exponential decay kinetics. Many processes, including radioactive decay of nuclides follow this type of rate law.

---

9.4: First-Order Reactions Show an Exponential Decay of Reactant Concentration with Time is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by LibreTexts.

- **28.3: First-Order Reactions Show an Exponential Decay of Reactant Concentration with Time** is licensed CC BY-NC-SA 4.0.
- **11.5: 1st order rate law** by Patrick Fleming is licensed CC BY-NC-SA 4.0.