ChemQuest 44

Concentration and Time

Name: ______________________________

Date: ________________

Hour: _____

Information: First Order Reactions with One Reactant

As we consider what affects the rate of reactions it is desirable to examine how the concentration of a reactant changes with time. Let us consider reactions that have only one reactant and we will further restrict our considerations to first order reactants. As an example, consider the following reaction:

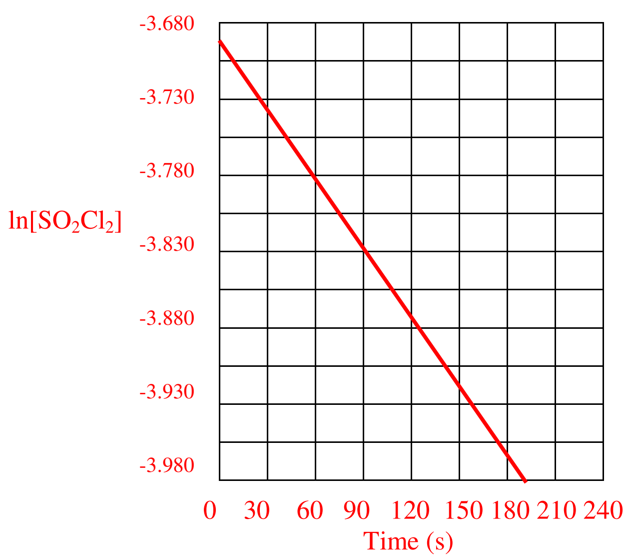
$$SO_2Cl_2 \rightarrow SO_2 + Cl_2$$

Table 1: Experimental data for the decomposition of SO_2Cl_2

Time (s)	**[SO_2Cl_2]**
0	0.0250
60	0.0228
120	0.0208
180	0.0190

It can be shown that the natural log of the concentration of a first order reactant varies directly with the time. So in this case ln[SO_2Cl_2] varies in direct proportion to the time.

1. Using the above data, prove on the graph below that **ln[SO_2Cl_2] = - kt + ln[SO_2Cl_2]$_0$** is a straight line when graphed. Note the expression [SO_2Cl_2]$_0$ is the concentration of SO_2Cl_2 at a time of zero seconds. **Label the axes**.



Calculate ln[SO_2Cl_2] values and plot:

Time	**ln[SO_2Cl_2]**
0	-3.689
60	-3.781
120	-3.873
180	-3.963

2. Given this relationship between concentration and time (ln[SO_2Cl_2] = - kt + ln[SO_2Cl_2]$_0$), find the rate constant k.

Choose values to plug into equation; I'll use at time 120:

ln(0.0208) = -k (120) + ln(0.0250) → k = 0.00153 1/s

3. Find the half-life for this reaction. What this means is that you need to find the time it takes for half of the reactant to get used up.
   Find the time (t) when $[SO_2Cl_2] = 1/2(0.0250) = 0.0125$
   $\ln(0.0125) = -(0.00153)(t) + \ln(0.0250) \rightarrow t = 453$ seconds

Information: Second Order Reactions with One Reactant

Consider the following reaction: $2\ NO_2 \rightarrow 2\ NO + O_2$. The following experimental data was gathered for this reaction:

Table 2: Experimental data for the decomposition of NO_2

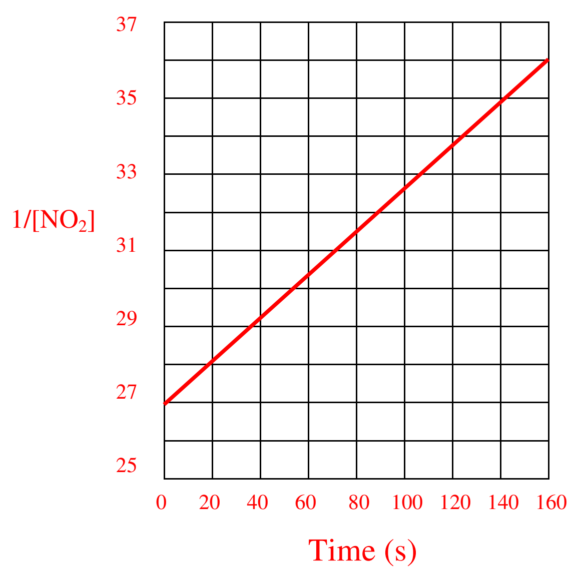
Time (s)	**$[NO_2]$**
0	0.0370
45	0.0338
90	0.0311
135	0.0288

If you attempted a plot of ln vs. t as you did in question 2 above you would not get a straight line. Instead, for second order reactants, the inverse of the concentration varies directly with time.

Critical Thinking Questions

4. Using the following graph and the above data, prove that the following equation yields a straight line.

$$\frac{1}{[NO_2]} = kt + \frac{1}{[NO_2]_0}$$



Calculate $1/[NO_2]$ and plot this data:

Time (s)	$1/[NO_2]$
0	27.03
45	29.59
90	32.15
135	34.72

5. What is the value of the rate constant, k, for this reaction?
   $1/0.0311 = k\ (90) + 1/0.0370 \rightarrow k = 0.0570\ 1/Ms$

6. Find the half-life for this reaction.

   Need to find the time, t, when $[NO_2] = 1/2(0.0370) = 0.0185$ M

   $1/0.0185 = (0.0570)(t) + 1/0.0370 \rightarrow t = 474$ s

Skill Practice Question

7. Given the following reaction and table of experimental data, answer the following questions.

$$2\ N_2O_5 \rightarrow 4NO_2 + O_2$$

Time (s)	**$[N_2O_5]$**
0	0.0200
100	0.0169
200	0.0142
300	0.0120
400	0.0101
500	0.0086
600	0.0072
700	0.0061

a) Is the reaction 1st order or second order with respect to N_2O_5? How do you know?

   It is 1st order because the data fits the equation $\ln[N_2O_5] = -kt + \ln[N_2O_5]_0$ much more closely than it fits the 2nd order equation.

b) What is the value for the rate constant?

   Using $\ln[N_2O_5] = -kt + \ln[N_2O_5]_0$ and plugging in data…

   $\ln(0.0086) = -k(500) + \ln(0.0200) \rightarrow k = 0.0017$ 1/s

c) What is the half life for this reaction?

   $\ln(0.0100) = -(0.0017)(t_{1/2}) + \ln(0.0200) \rightarrow t = 408$ s

d) How many seconds are required for the concentration of N_2O_5 to reach a level of 0.0025 M?

   $\ln(0.0025) = -(0.0017)(t) + \ln(0.0200) \rightarrow 1223$ s