Kinetics

So many equations…so many units…

Summary of Kinetics Equations			
Order	**Zero**	**First**	**Second**
Rate Law *Differential Rate Law - Comparing rate to concentration*	Rate = k	Rate = k[A]	Rate = $k[A]^2$
Integrated Rate Law *y = mx + b* *Comparing concentration over time*	$[A] = -kt + [A]_0$	$\ln [A] = -kt + \ln[A]_0$	$\frac{1}{[A]} = kt + \frac{1}{[A]_0}$
Plot needed to give a straight line *"Graph C, N, R"*	$[A]$ versus t	$\ln[A]$ versus t	$\frac{1}{[A]}$ versus t
Relationship of rate constant (k) to the slope of the straight line	Slope = -*k*	Slope = -*k*	Slope = *k*
Units on rate constant (k)	$\frac{M}{s} = Ms^{-1} = \frac{mol}{L \bullet s}$	$\frac{1}{s} = s^{-1}$	$\frac{1}{M \bullet s} = M^{-1}s^{-1} = \frac{L}{mol \bullet s}$
Half Life Equation *Use integrated law when solving other half life related problems*	$t_{1/2} = \frac{[A]_0}{2k}$	$t_{1/2} = \frac{0.693}{k}$	$t_{1/2} = \frac{1}{k\,[A]_0}$

Arrhenius Equation

$$k = Ae^{-Ea/RT}$$

k = rate constant
Ea = Activation Energy
T = Temperature
A = Frequency Factor
R = 8.31 J/mol•K

When Graphing…

Graph it as ln(k) versus $\frac{1}{T}$ *(y versus x)*

$$\ln(k) = \left(-\frac{E_a}{R}\right)\left(\frac{1}{T}\right) + \ln(A)$$

y = m x + b

$$\ln\left(\frac{k_2}{k_1}\right) = \left(\frac{E_a}{R}\right)\left(\frac{1}{T_1} - \frac{1}{T_2}\right)$$

<u>Finding Units for k</u>

Remember:

$$rate = k[A]^x[B]^y\ etc\ldots$$

Rearrange:

$$k = \frac{rate}{[A]^x[B]^y\ etc\ldots}$$

Remember:

$$rate\ units = \frac{M}{s}$$
$$Concentration\ unts = M$$
$$Overall\ Order = (x + y + etc\ldots)$$

Substitute in your units and rewrite:

$k = \frac{M/s}{M^{(x+y+etc\ldots)}}$ → $k = \frac{M}{M^{(x+y+etc\ldots)} \bullet s}$ → **then cancel out units**

Units for k based on overall order of reaction $k = \frac{M}{M^{(x+y+etc\ldots)} \bullet s}$		
Overall Order	**Example of Units Plugged In**	**Final Units for k**
0	$k = \frac{M}{M^{(0)} \bullet s} = \frac{M}{1 \bullet s}$	$\frac{M}{s} = Ms^{-1}$
1	$k = \frac{M}{M^{(1)} \bullet s} = \frac{\cancel{M}}{\cancel{M} \bullet s}$	$\frac{1}{s} = s^{-1}$
2	$k = \frac{M}{M^{(2)} \bullet s} = \frac{\cancel{M}}{\cancel{M} \bullet M \bullet s}$	$\frac{1}{M \bullet s} = M^{-1}s^{-1}$
3	$k = \frac{M}{M^{(3)} \bullet s} = \frac{\cancel{M}}{\cancel{M} \bullet M \bullet M \bullet s}$	$\frac{1}{M^2 \bullet s} = M^{-2}s^{-1}$
4	$k = \frac{M}{M^{(4)} \bullet s} = \frac{\cancel{M}}{\cancel{M} \bullet M \bullet M \bullet M \bullet s}$	$\frac{1}{M^3 \bullet s} = M^{-3}s^{-1}$
Etc…etc…etc…		

Remember: $M = \frac{mol}{L}$ $\frac{1}{M} = M^{-1} = \frac{L}{mol}$

↑

You may see this substituted into k units.

For example: $M^{-1}s^{-1} = \frac{L}{mol \bullet s}$

Using Logarithms

There is no way I can show you every version and rearrangement that you may come across during the year. Here are some common ones, some to help jog your memory. Remember that I am a Chemistry teacher, not a Math teacher…maybe Math-Land has better ways to show these! If you have something awesome from a math teacher then share it with me – ha!

	General	
	Logarithm Form	Exponent Form
Equations	$\log_a N = x$	$N = a^x$
Example	$\log_4 8 = 1.5$	$8 = 4^{1.5}$

	Base Ten	
	Logarithm Form	Exponent Form
Equations	$\log N = x$	$N = 10^x$
Example	$\log 100 = 2$	$100 = 10^2$

	Natural Logarithms	
	Logarithm Form	Exponent Form
Equations	$\ln N = x$	$N = e^x$
Example	$\ln 6 = 1.79$ *rounded*	$6 = e^{1.79}$ *rounded*

	Subtracting and Dividing Natural Logarithms	
	Subtraction Form	Division Form
Equations	$\ln(A) - \ln(B)$	$\ln\left(\frac{A}{B}\right)$
Example	$\ln(15) - \ln(3)$	$\ln\left(\frac{15}{3}\right)$

	Normal Radioactive Half Life Logarithms	
	Subtraction Form	Division Form
Equations	$\frac{A_E}{A_S} = 0.5^{\left(\frac{t}{h}\right)}$	$\log\left(\frac{A_E}{A_S}\right) = \frac{t}{h}\log(0.5)$
Example	$\frac{3}{140} = 0.5^{\left(\frac{t}{24}\right)}$	$\log\left(\frac{3}{140}\right) = \frac{t}{24}\log(0.5)$

Just *ONE* Chemistry Example of Using Natural Logarithms

Maybe you want to find out what fraction of a chemical you have after a certain time has passed. Let's say that you know it is a first order reaction. Remember that Integrated Rate Laws show you Concentration vs. Time. So start there! Remember that the fraction you have left is $\frac{[A]}{[A]_0}$

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

$$\downarrow$$

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

$$\downarrow$$

$$\frac{\ln[A]}{\ln[A]_0} = -kt$$

$$\downarrow$$

$$\ln\left(\frac{[A]}{[A]_0}\right) = -kt$$

$$\downarrow$$

$$\left(\frac{[A]}{[A]_0}\right) = e^{-kt}$$

$$\downarrow$$

Now plug in your value of k (rate constant) and t (time that has passed) and you can find your fraction left! Multiply it by 100 and you would have % left!

Here is an Excel spreadsheet I made that is programed to automatically graph the various plots for you 😊

https://tinyurl.com/yr7xzb75