1. Consider the following reactions. Determine the order of the reaction and write the simplest rate law possible (e.g. 3rd order would be rate=$k[A]^3$) (a. rate = k[A] b. rate = k)

Reaction	k_1
A	1136 s^{-1}
B	83822 M s^{-1}

2. For the reaction below, use the method of initial rates to determine the rate constant and rate law. Make sure to use the correct units. (rate = 0.5 $M^{-1}s^{-1}[NO_2]^2$)

$$CO\ (g) + NO_2\ (g) \rightarrow NO\ (g) + CO_2\ (g)$$

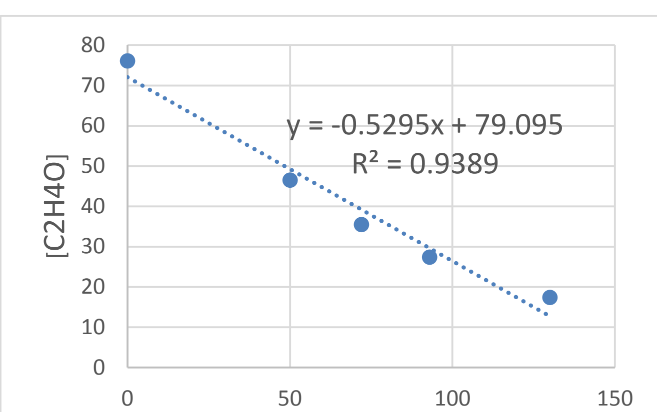
Experiment	$[NO_2]$ (M)	[CO] (M)	Rate (M s^{-1})
1	0.15	0.15	0.011
2	0.30	0.15	0.045
3	0.60	0.30	0.18
4	0.60	0.60	0.18

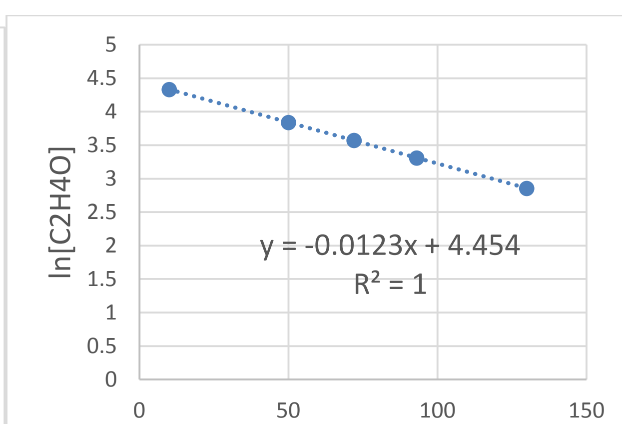
3. For the reaction in problem 2, determine the **rate of the reaction** when the concentration of each reactant is 0.25 M. (0.03125 M/s)

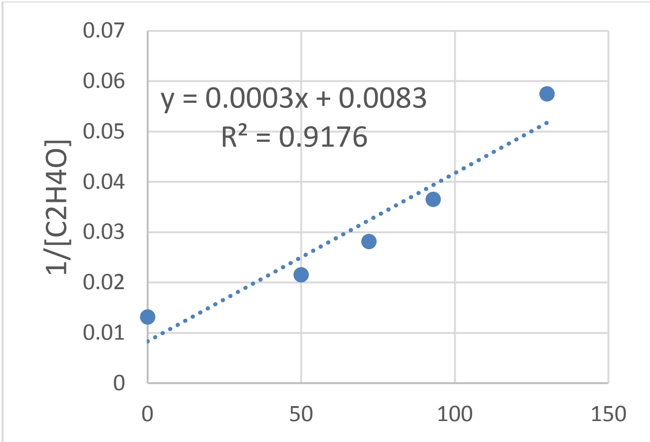
4. Consider the following data.

$C_2H_4O\ (g) \rightarrow CH_4\ (g) + CO\ (g)$	
Time (sec)	**$[C_2H_4O]$ (mM)**
10	76.0
50	46.5
72	35.5
93	27.4
130	17.4

a. Determine the rate law (including the rate constant with correct units) rate = 0.0123$s^{-1}[C_2H_4O]$)







b. Determine the reactant concentration after 25 seconds has passed. (63.23 mM)
c. Determine the initial concentration of C_2H_4O (86 mM)
d. Determine the initial rate of the reaction. (1.0578 M/s)
e. The concentration of all reactants and products after 85 seconds have passed.
   ($[C_2H_4O]$ = 30.22 mM [CO] = 55.75 mM] $[CH_4]$ = 55.75 mM)

5. Consider the synthesis of $C_2H_4O_2$ from solid carbon, oxygen gas (O_2), and hydrogen gas (H_2). Using the information below, determine the initial concentration of H_2 (210 mM)

$[C_2H_4O_2]$ = 100 mM and $[H_2]$ = 10 mM after 10 minutes.

Concept Questions:

1. What is activation energy and how can it be decreased?
2. What are 3 ways to change the rate of a reaction?
3. Draw a reaction coordinate and label it with all important energy levels. How does this help us explain reaction rates?
4. Consider two reactions with identical rate constants – one of these reactions is 1st order and the other is 2nd order. Explain why the rate of the 2nd order reaction will decrease more quickly than the rate of the 1st order reaction.

1. a) $k \equiv s^{-1}$ ← 1st order units   rate $= k[A]$

b) $k \equiv M s^{-1}$ ← 0th order   rate $= k$

2. rate $= k[NO_2]^a[CO]^b$

1) $\frac{0.011}{0.045} = \frac{k(0.15)^a(0.15)^b}{k(0.3)^a(0.15)^b}$

$0.244 = 0.5^a$

$\ln 0.244 = a \ln 0.5$

$a = 2$

2) $\frac{0.18}{0.18} = \frac{k}{k} \cdot \frac{(0.6)^a}{(0.6)^a} \cdot \frac{(0.3)^b}{(0.6)^b}$

$1 = 0.5^b$

$\ln 1 = b \ln 0.5$

$b = \varnothing$

$0.045 \frac{M}{s} = k(0.3)^2(0.15)^0$ $k = 0.5\ M^{-1}s^{-1}$

rate $= 0.5\ M^{-1}s^{-1}[NO_2]^2$

3. rate $= 0.5\ M^{-1}s^{-1}(0.25\ M)^2 = 0.03125\ M\ s^{-1}$

4. a) plot of ln A vs. t is linear ($r^2 = 1$)   slope $= -0.0123$

1st order $k = 0.0123\ s^{-1}$ rate $= 0.0123\ s^{-1}[C_2H_4O]$

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

$\ln[A] = -0.0123\ s^{-1}(25\ s) + \ln 86$

$\ln[A] = 4.147$

$[A] = 63.23\ mM$

c) from the graph, $y = -0.0123x + 4.454$

y ↑ $\ln[A]$, -0.0123 ↑ k, x ↑ t, 4.454 ↑ $\ln[A]_0$

$\ln[A]_0 = 4.454$

$[A]_0 = 85.97\ mM$ (this is done using inverse ln on your calculator)

d) $\text{rate} = 0.0123\ s^{-1}\ (85.97\ mM) = 1.057\ \frac{mM}{s}$

e. Use average rate approach!

$[C_2H_4O]_0 = 85.97\ mM$ (@ $t = 0$)

$[C_2H_4O]_{85} = \underline{?}$ → $\ln[A] = -0.0123\ (85) + 4.454$

$\ln[A] = 3.4085$

$[A] = 30.22\ mM$

$$\text{rate} = -\frac{\Delta[C_2H_4O]}{\Delta t} = \frac{\Delta[CH_4]}{\Delta t} = \frac{\Delta[CO]}{\Delta t}$$

$$\text{rate} = -\frac{30.22 - 85.97}{85 - 0} = 0.6559\ \frac{mM}{s}$$

$[CO]_0 = 0$ (b/c a product)

$[CO]_{85} = ?$

$$0.6559 = \frac{x - 0}{85 - 0} = 55.75\ mM$$

$[CH_4]_0 = 0$

$[CH_4]_{85} = x$

$$0.6559 = \frac{x - 0}{85} = 55.75\ mM$$

5. $2C(s) + O_2(g) + 2H_2(g) \rightarrow C_2H_4O_2$

$$rate = \frac{\Delta[C_2H_4O_2]}{\Delta t} = -\frac{1}{2}\frac{\Delta[H_2]}{\Delta t}$$

$$rate = \frac{100 - 0\ mM}{10 - 0\ min} = \frac{10\ mM}{min}$$

$$\frac{10\ mM}{min} = -\frac{1}{2}\ \frac{10 - x}{10 - 0} = 210\ mM$$

① The energy barrier that a reaction MUST overcome for reactants to be converted to products.

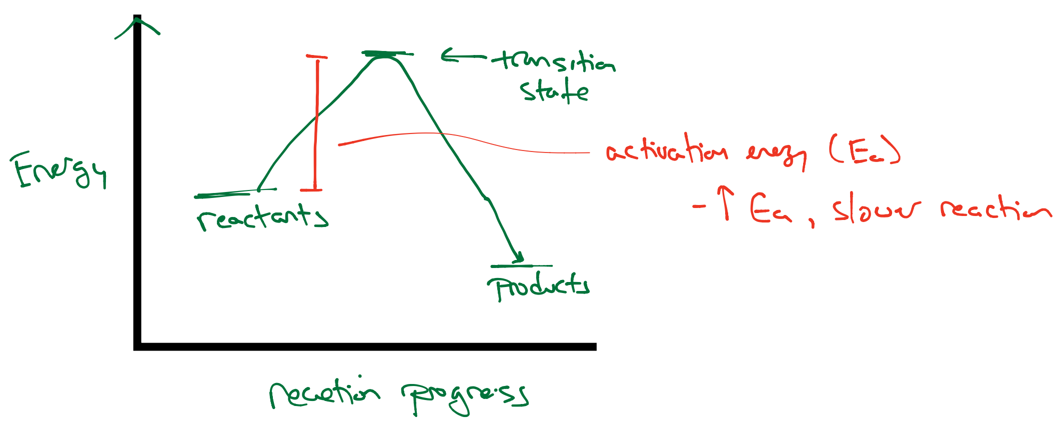
- adding a catalyst will decrease the Ea

② Change the concentration

add a catalyst

Change the Temperature

③



④ 1st rate = k [A]¹

2nd rate = k [A]² ← more dependent on changing concentration because 2 vs. 1