PS5key

Monday, March 20, 2017 7:25 AM

Problem Set 5 **(Due: March 10th 5:00 PM)**

1. The gas phase decomposition if N_2O_4 to NO_2 is a first order reaction. Use the following data to answer each of the following questions:

Experiment	Temperature (°C)	Initial [N_2O_4] (M)	Initial Rate (M s^{-1})
1	25	0.1	5×10^{3}
2	40	0.15	2.3×10^{4}

   a. Determine the rate constant at 25 °C.
   b. Calculate the activation energy.
   c. Calculate the pre-exponential factor.
   d. What is the rate constant at 85 °C?
   e. How much N_2O_4 will be left if 100 mM is allowed to decompose for 15 μs? What concentration of NO_2 has been created?
   f. How long will it take for 50% of the N_2O_4 in experiment 2 to decay? Report your answer in μs.

2. Sketch a reaction coordinate and clearly label the activation energy. On the same sketch, show a catalyzed reaction pathway. Why does a catalyst increase the rate of a reaction?

3. The following reaction has an activation energy of 6.3 kJ mol^{-1} and a pre-exponential factor of 6.0×10^{8} $M^{-1}s^{-1}$.

$$NO\ (g) + F_2\ (g) \rightarrow NOF\ (g) + F_2\ (g)$$

   a. What is the order of this reaction? Recall that A has the same units as the rate constant.
   b. Calculate the rate constant at 25°C.
   c. The product of this reaction is nitrosyl fluoride. This compound is typically written as NOF, but different arrangements of atoms are possible. Draw the correct Lewis structure for nitrosyl fluoride (make sure to consider atom arrangement and formal charge).
   d. What is the molecular geometry of NOF?

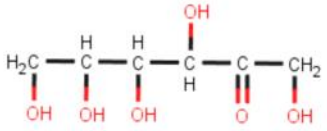
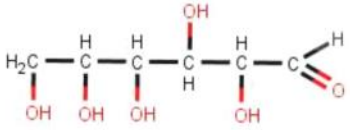
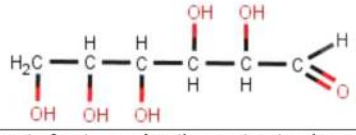
4. Lactate dehydrogenase (LDH) is responsible for converting pyruvate to lactic acid. This is an important reaction during anaerobic respiration. The product is the reason why your muscles get sore after an intense workout.
   a. Look up the structures of lactic acid and pyruvate and sketch them.
   b. LDH needs to be able to bind to pyruvate for a reaction to occur (i.e. to make an ES complex). Predict what the active site of the enzyme might look like so that it will recognize and bind to pyruvate.
   c. Using the following experimental data for an **uncatalyzed first order reaction**, determine the rate law of this reaction (including the rate constant). You should be able to copy and paste this data directly into Excel.
   d. How much lactic acid will be produced in 2 seconds if the starting concentration of pyruvate is 10 mM?

Time (min)	[Pyruvate] (M)
0	1.025
2	1.023
4	1.022
6	1.020
8	1.019
10	1.017
12	1.016
14	1.015

5. An enzyme catalyze reaction ($[E]_{total}$ = 100 nM) has a Km of 100 μM and Vmax of 15 nM min^{-1}. Determine the turnover number and catalytic efficiency.

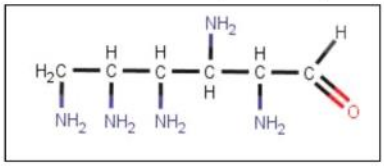
6. Using LeChatlier's principle to guide your answer, discuss why Km changes when a competitive inhibitor is added to an enzyme reaction. Do the same for an uncompetitive inhibitor.

7. Hexokinase is an enzyme that catalyzes the first step in glycolysis, the conversion of glucose to glucose-6-phosphate. However, this enzyme can also use a number of other sugars as substrates. These sugars only differ by the orientation of an alcohol group on the carbon backbone. The table below summarizes the structures and kinetic information about each sugar.

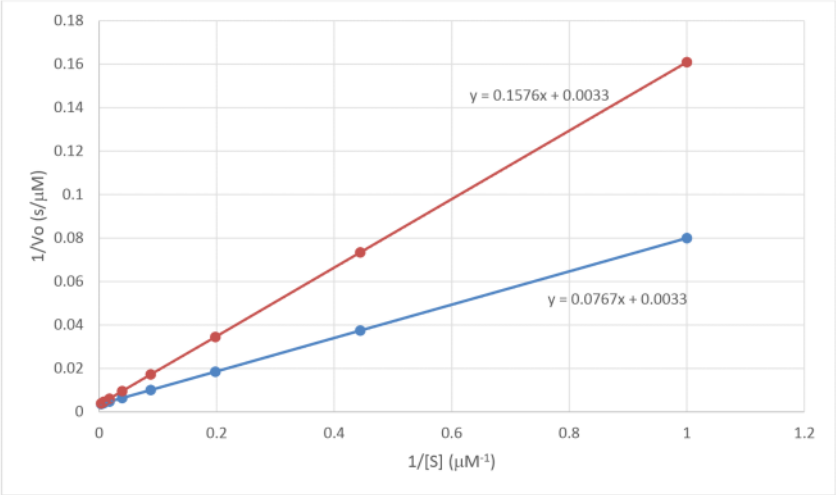
	Structure	k_{cat} (s^{-1})	K_M (mM)
Fructose		3.69	5.2
Glucose		5.01	0.023
Mannose		3.78	0.03

   a. Compare glucose to fructose. Are these structural or stereoisomers?
   b. Which substrate will bind to hexokinase with the highest affinity?
   c. How many molecules of glucose will be converted to product in two minutes? How about mannose?
   d. Compare the structures of these three sugars. Why do you think that fructose has such a different Km?
   e. Glucosamine is a suspected inhibitor of hexokinase. Below are plots of data collected with (orange line) and without (blue line) 20 mM glucosamine added.
      i. Is glucosamine an inhibitor of hexokinase?
      ii. What type of inhibitor is this? How do you know?
      iii. Determine K_I
   f. ADP is an uncompetitive inhibitor of hexokinase.
      i. What does this mean?
      ii. Sketch a Lineweaver Burk that shows an experiment that is inhibited by ADP compared to an uninhibited reaction.

8. Explain why this molecule could be a good competitive inhibitor of hexokinase.



Graphs for Problem 7e:



(1) a. $rate = k[N_2O_4]$ $\quad 5\times10^{-3} = k(0.1)$

$\boxed{k = 5\times10^{-4}\ s^{-1}}$

b. $k_1 = 5\times10^{-4}$ $\quad T_1 = 298.15$

$k_2 = ?$ $\quad T_2 = 313.15$

$2.3\times10^{-4} = k_2\ 0.15$

$k_2 = 1.53\times10^{-5}$

$$\ln\frac{1.53\times10^{-5}}{5\times10^{-4}} = \frac{-E_a}{8.314}\left(\frac{1}{313.15} - \frac{1}{298.15}\right)$$

$$1.118 = 1.93\times10^{-5}\,E_a$$

$\boxed{E_a = 57949\ J/mol}$

c. $k = Ae^{-E_a/RT}$

$5\times10^{-4} = Ae^{-57949/8.314\cdot298.15}$

$\boxed{A = 7.23\times10^{14}\ M s^{-1}}$

d. $k = 7.23\times10^{14}\, e^{-57949/8.314\cdot358.15}$

$\boxed{k = 2.6\times10^{6}\ s^{-1}}$

e. $\ln[N_2O_4] = -kt + \ln[N_2O_4]_0$

$\ln[N_2O_4] = -5\times10^{-4}\,s^{-1}(15\times10^{-6}) + \ln 100$

$\ln[N_2O_4] = 3.855$

$\boxed{[N_2O_4] = 47.24\ mM}$

$[N_2O_4] = 47.24\ mM$

$N_2O_4 \rightarrow 2NO_2$ $\quad 100 - 47.24 = 52.76\ mM$ used

If 52.76 mM N_2O_4 is used, 52.76×2 NO_2 is made

$[NO_2] = 105.52\ mM$

f. $\ln[N_2O_4] = -1.53 \times 10^5 s^{-1}\, t + \ln([N_2O_4]_0$

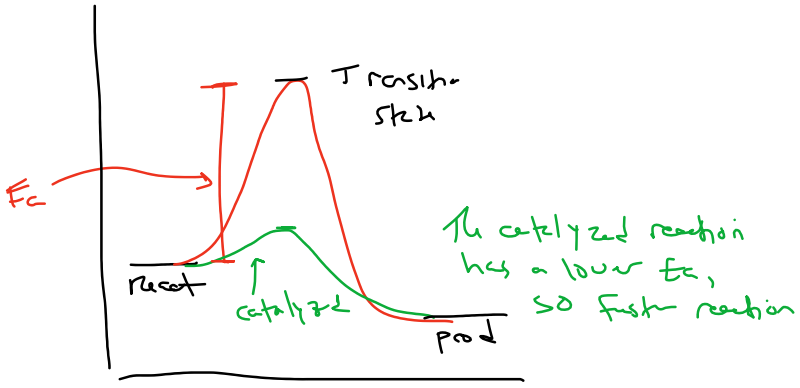
$\ln \frac{[N_2O_4]}{[N_2O_4]_0} = -1.53 \times 10^5 s^{-1}\, t$

$\ln \frac{1}{2} = -1.53 \times 10^5 s^{-1}\, t$

$t = 4.53 \times 10^{-6}\ s$

$4.53\ \mu s$

2.

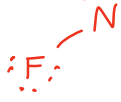


3. a. 2nd order $(M^{-1}s^{-1})$

b. $k = Ae^{-E_a/RT}$

$6.3\ kJ/mol = 6300\ J/mol$

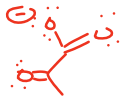
$k = 6 \times 10^8\ M^{-1}s^{-1}\, e^{\frac{-6300}{8.314 \cdot 298.15}} = 4.72 \times 10^7\ M^{-1}s^{-1}$

c.  only arrangement with no formal charge

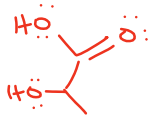
d. bent

4. a. 

4. a.

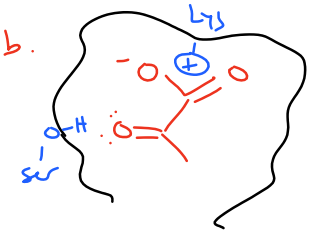


pyruvate



lactic acid

b.



c. 1st order

plot: slope = -7.1×10^{-4}

int = 0.0244

rate = $7.1 \times 10^{-4}\ min^{-1}\ [Pyruvate]$

d. $\ln[A] = -7.1 \times 10^{-4} \left(\frac{2}{60}\ min\right) + \ln 10$

$\ln[A] = 2.30256$

$[A] = 9.99976\ mM$

pyruvate used = $10 - 9.99976 = 2.37 \times 10^{-4}\ mM$

lactic acid made = $2.367 \times 10^{-4}\ mM$

5. $k_{cat} = \frac{15\ nM/min}{100\ nM} = 0.15\ min^{-1}$ = turnover #

Cat. eff. = $\frac{0.15\ min^{-1}}{100\ mM} = 1.5 \times 10^{-3}\ mM^{-1} min^{-1}$

6.

Competitive

$E + S \rightleftharpoons ES \rightarrow E + P$

\+

I

I

EI

Equilibrium shifts left because presence of EI complex. K appears to be lower affinity. K_M increases

uncompetitive

$E + S \rightleftharpoons ES \rightarrow E + P$

\+

I

I

Equilibrium appears to favor ES because of

I
↗
ESI

Equilibrium appears to favor ES because of ESI. K_M decreases

7. a. structural – the carbonyl/alcohol groups move

b. lowest K_M → glucose

c. glucose: $\frac{120\ s \mid 5.01}{s} = 601.2$

mannose: 453.6

d. different geometry around 1st + 2nd carbons (sp^2 vs. sp^3)

e. i) yes

ii) competitive – V_{max} (y-int) stays the same but K_M changes (slope changes)

iii) $V_{max} = \frac{1}{int} = \frac{1}{0.0033} = 303 \frac{\mu M}{s}$

- inh: $K_M = m(V_{max}) = 23.24\ \mu M$

+ inh: $K_M' = m(V_{max}) = 47.76\ \mu M$

$K_M' = K_M \alpha$ $\quad 47.76 = 23.24\ \alpha$

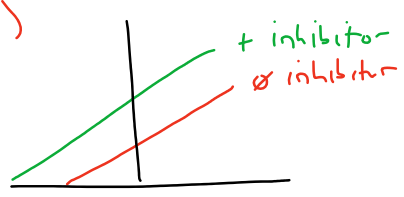
$\alpha = 2.055$

$2.055 = 1 + \frac{[I]}{K_I} = 1 + \frac{20 mM}{K_I}$

$K_I = 18.96\ mM$

f. i) it binds to the ES complex + decreases K_M + V_{max} \ not to active site!

ii)



8. The only changes are $OH \rightarrow NH_2$

- the amine keeps all H-bonding ability