☆ Two versions of this test were given, though the problems were similar. See me with any questions. ☆

Name Mr. Shank Class AP 1, 2, 3

Pre-AP Chemistry, Grade 10
Test 3: Kinetics

Useful Information: R = 8.314 J/mol K

I. Multiple Choice

1. Which one of the following does not affect the rate of a chemical reaction?
   a) Temperature
D b) Activation Energy
   c) Addition of a Catalyst
   d) Free Energy Change
   e) Concentration of Reactants

2. A particular reaction has the rate law $r = k[A]^x[B]^y$. If the reaction is first-order with respect to A and third-order with respect to B, what are the units of k?
   a) Ms^{-1}
D b) $M^{-1}s^{-1}$
   c) $M^{-2}s^{-1}$
   d) $M^{-3}s^{-1}$
   e) $M^{-1}s$

3. Holding everything else constant, it was found that the rate of the reaction below increased by a factor of 27 when the initial concentration of C_3 was increased by a factor of 9. What is the order of the reaction with respect to C_3?

   $2C_3 + 3D \rightarrow 3C_2D$

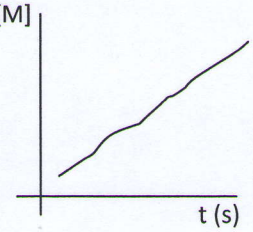
E a) 0
   b) 1/2
   c) 2/3
   d) 1
   e) 3/2

4. The occurrence and rate of chemical reaction depend on
   a) Collision frequency
   b) Collision energy
E c) Collision orientation
   d) Only two of the above
   e) All of the above

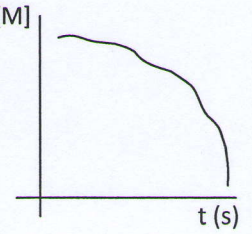
This problem was thrown out.

5. Which of the following graphs most closely shows the change in the concentration of a reactant (A) over time during a chemical reaction? (Assume the reaction rate depends on the concentration of A).

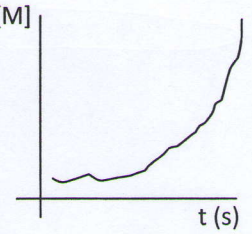
a) A [M]



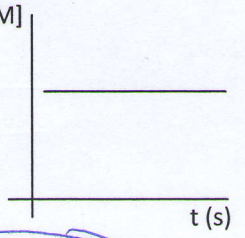
b) A [M]



c) A [M]

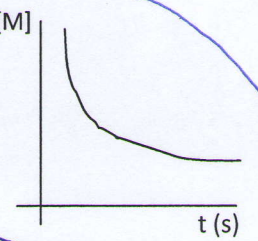


d) A [M]



E

e) A [M]



6. The highest-energy species on a reaction profile is called the

B

a) Equilibrium
b) Transition State
c) Reactants
d) Products
e) Minimum

7. As activation energy decreases, k

A

a) Increases
b) Decreases
c) Remains Constant

8. Consider the following reaction and its associated rate law:

A

$A + B \rightarrow C \qquad r = k[B]^2$

Which of the following will not increase the rate of the reaction?

a) Increasing the concentration of A
b) Increasing the concentration of B
c) Increasing the temperature of the reaction
d) Adding a suitable catalyst

9. Ozone (O_3) in the atmosphere is converted to oxygen by the following two reactions

$$NO_{(g)} + O_{3(g)} \rightarrow NO_{2(g)} + O_{2(g)}$$
$$NO_{2(g)} + O_{(g)} \rightarrow NO_{(g)} + O_{2(g)}$$

Identify the catalyst and the type of catalysis responsible for the atmospheric conversion of ozone. (Hint: Use Hess's Law to first determine the overall reaction).

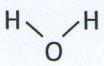
C

	Catalyst	Type of Catalysis
a)	NO	Heterogeneous
b)	NO_2	Heterogeneous
c)	NO	Homogeneous
d)	NO	Enzyme
e)	O_2	Homogeneous

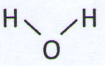
10. Which of the following orientations is most likely to lead to a collision that will complete the following reaction?

$$HCl_{(aq)} + H_2O_{(l)} \rightarrow H_3O^+_{(aq)} + Cl^-_{(aq)}$$

D

a) H—Cl 

b) H—Cl 

c) Cl—H 

d) Cl—H 

II. Free Response

1. Consider the following reaction of carbonic acid with water

$$H_2CO_3 + H_2O \rightarrow H_3O^+ + HCO_3^-$$

$r = k_f[H_2CO_3]$

$k_f = \frac{r}{[H_2CO_3]}$

Experiment	$[H_2CO_3]$ (M)	r (M/s)
1	0.01	4.0×10^{-3}
2	0.03	1.2×10^{-2}
3	0.02	1.0×10^{-2}

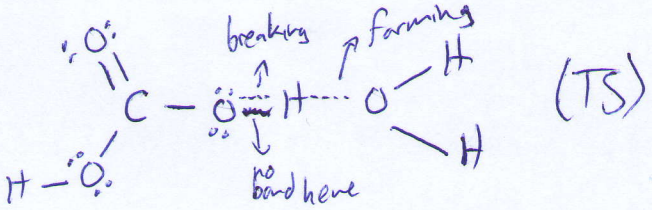
$k_f = 4\times10^{-3}/.01 = 0.4$

$k_f = 1.2\times10^{-2}/.03 = 0.4$

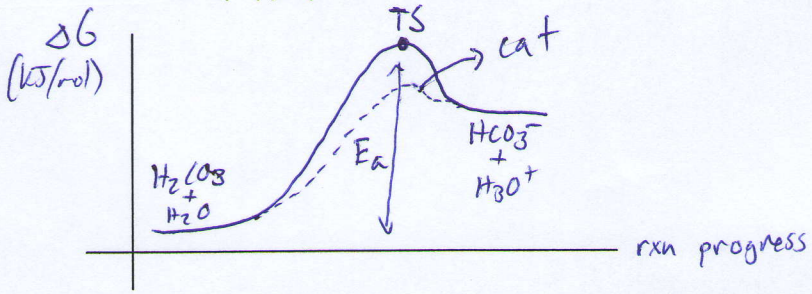
$k_f = 1.0\times10^{-2}/.02 = 0.5$

*All experiments conducted at 298 K.

a) Draw a reasonable transition-state structure for the reaction above. (Hint: in H_2CO_3, all three oxygen atoms are bonded to carbon, and all hydrogen atoms are bonded to different O atoms.)



b) Draw a reaction profile for the reaction above on the axes below. To get ANY credit, you **must** label <u>both</u> axes with titles and any appropriate units.



c) On your graph above, label the reactants, products, transition state, and activation energy.

d) Draw a (- - - -) curve on the same graph showing the effect of a catalyst. Label the curve 'cat'.

The rate law for this reaction in the forward direction (shown above) is

$$r = k_f[H_2CO_3]$$

Experiment 1 in the rate table is uncatalyzed. One of the other two experiments is catalyzed.

e) Identify which of the other two experiments is catalyzed. Explain your answer.

Catalyzed (circle one): Experiment 2 (Experiment 3)

Explanation: The rate constant for experiment 3 is greater than the rate constant for experiments 1 & 2. At the same temperature for the same reaction, this indicates a lower activation energy for experiment 3, as seen in the equation $k = Ce^{-Ea/RT}$. Catalysts increase k by decreasing Ea, so experiment 3 is catalyzed.

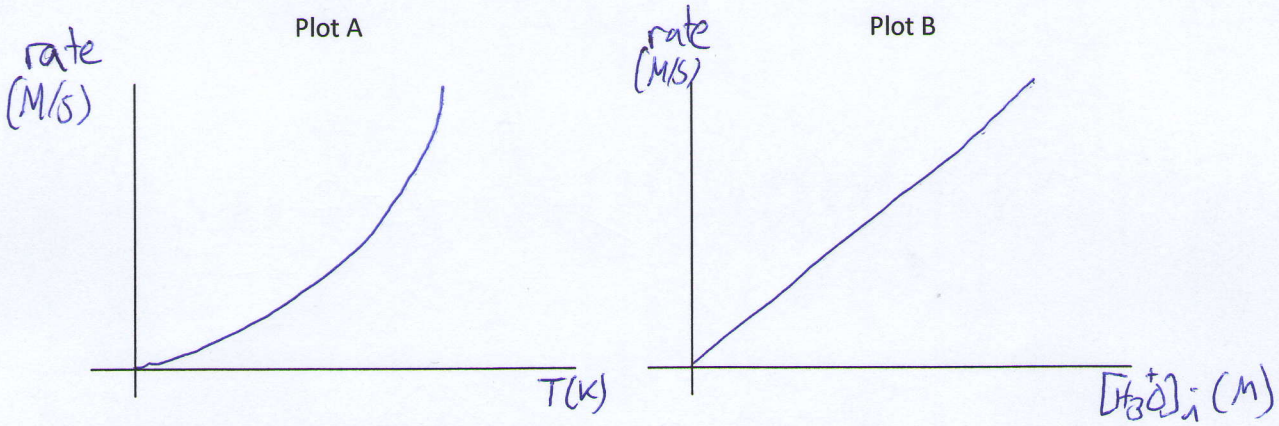
2. Consider the following reaction (the reverse of the reaction in the previous question):

$$H_3O^+ + HCO_3^- \rightarrow H_2CO_3 + H_2O$$

$$r = k[H_3O^+][HCO_3^-]$$

$$k_r(298\ K) = 8.9 \times 10^5$$

a) Draw a curve on "Plot A" below to show the effect of increasing temperature on the rate of the reaction. To get ANY credit, you **must** label <u>both</u> axes with titles and units.



b) Explain, in words, your graph in part (b).

The rate of a chemical reaction increases with increasing temperature because, at higher temperatures, a greater percentage of molecules have enough kinetic energy to climb the activation-energy barrier to reach products. The shape of the curve is exponential, as given by $k = Ce^{-Ea/RT}$.

c) Draw a curve on "Plot B" above to show the effect of increasing the initial concentration of H_3O^+ on the rate of the reaction. To get ANY credit, you **must** label <u>both</u> axes with titles and units.

d) Explain, in words, your graph in part (c).

The rate of a chemical reaction increases with increasing initial concentration because, at higher concentrations, molecules collide more frequently, increasing the rate of "successful" collisions that result in product formation. The shape of the curve is given by $r = k[H_3O^+][HCO_3^-]$, where the rate depends linearly on the concentration of $[H_3O^+]$.

3. At **equilibrium**, the rate of the forward reaction (in Free Response # 1) and the rate of the reverse reaction (in Free Response # 2) are equal.

At a given temperature, the ratio of the rate constant for the forward reaction (k_f) and the rate constant for the backward reaction (k_r) is also a constant.

a) What is the value of the ratio of rate constants at 298 K for the reactions in # 1 and # 2?

$k_r(298K) = 8.9 \times 10^5$ (from problem #2)

$k_f(298K) = 4 \times 10^{-1}$ (for uncatalyzed rxn in problem # 1)

$$\frac{k_f}{k_r} = \frac{4 \times 10^{-1}}{8.9 \times 10^5} = 4.5 \times 10^{-7}$$

$$\frac{k_f}{k_r} = 4.5 \times 10^{-7}$$

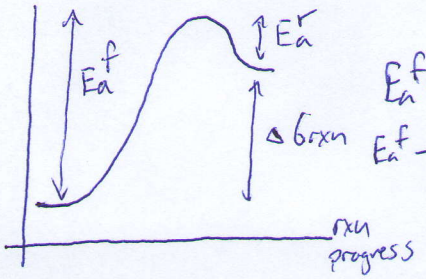
b) Calculate the free energy change for the reaction at 298 K: $H_2CO_3 + H_2O \rightarrow H_3O^+ + HCO_3^-$

$$\frac{k_f}{k_r} = \frac{Ce^{-E_a^f/RT}}{Ce^{-E_a^r/RT}} = e^{-\frac{1}{RT}(E_a^f - E_a^r)} = e^{-\frac{\Delta G_{rxn}}{RT}} \Rightarrow$$

$$\Delta G_{rxn} = -RT \ln \frac{k_f}{k_r}$$

$$= -RT \ln (4.5 \times 10^{-7})$$

$$= 36.2073 \text{ kJ/mol}$$



$E_a^f = E_a^r + \Delta G_{rxn}$

$E_a^f - E_a^r = \Delta G_{rxn}$

$\Delta G_{rxn} = 36.21$ kJ/mol

EC. The ratio $K_a = \frac{[HCO_3^-][H_3O^+]}{[H_2CO_3]}$ is called the acid dissociation constant for carbonic acid. Calculate the value of K_a at 298 K.

At equilibrium,

$$r_f = r_r$$

$$k_f[H_2CO_3] = k_r[H_3O^+][HCO_3^-]$$

$$4.5 \times 10^{-7} = \frac{k_f}{k_r} = \frac{[H_3O^+][HCO_3^-]}{[H_2CO_3]} = K_a$$

$K_a = 4.5 \times 10^{-7}$