AP Chem Rate of Reaction Review!

1. For the Reaction: $2A_{(g)} + BC_{2(g)} \text{ -------> } A_2B_{(g)} + 2\,C_{(g)}$

Trial #	Initial concentration of A(M):	Initial Concentration of BC_2 (M)	Initial rate of formation of A_2B (M/s)
1	0.050	0.050	0.00016
2	0.050	0.100	0.00064
3	0.10	0.200	0.00512

a. Find the rate law and the value of k, including units.
b. In trial 1, what was the initial rate of formation of C?
c. Predict the rate of disappearance of $A_{(g)}$ if both reactant starting concentrations are 0.030 M.
d. Calculate the intial rate of reaction (in terms of A_2B) if the initial concentrations of A and BC_2 are 0.15 M and 0.25 M, respectively.

2. $Cu_{(s)} + 4\,HNO_{3\,(aq)} \text{ -------> } Cu(NO_3)_{2(aq)} + 2\,NO_{2(g)} + 2\,H_2O_{(l)} + \text{heat}$
(colorless solution) (blue solution) (brown gas)

Suppose the above reaction is done by pouring 100.0 mL of 0.80 Molar nitric acid at 20.0˚C onto 50. grams of copper in the form 1.0 cm^3 cubes. How would the rate of reaction change if you changed the following things? (Increase? Decrease? Or no change?)

_____a. Change the concentration of nitric acid to 0.60 M.
_____b. Use 50. g of copper powder, instead of the cubes.
_____ c. Add 50.0 mL of water to the 100.0 mL of 0.80 M nitric acid, and then add this solution to the 1.0 cm^3 copper cubes, instead of the original solution. (still at 20.˚C)
_____d. Change the temperature of the acid to 30.0˚C

3. $2\ C_5H_6$ ------> $C_{10}H_{12}$
(cyclopentadiene) (dicyclopentadiene)

	Initial Concentration of C_5H_6(M/s)	Initital rate of formation of $C_{10}H_{12}$ (M/s)
Experiment 1	0.040	0.000267
Experiment 2	0.060	0.000601
Experiment 3	0.120	0.00240

a. Determine the rate law and the value of the rate constant.
b. How will the reaction rate be affected if the temp increases?
~~Explain your answer mathematically~~
Explain your answer in terms of what the molecules are doing
c. How will the reaction rate be affected if a catalyst is added?
~~Explain your answer mathematically~~
Explain in terms of what the molecules are doing
d. How is the reaction rate affected when the concentration of cyclopentadiene is increased?
Explain in terms of what the molecules are doing
e. If you start with a C_5H_6 molarity of 0.120 Molar, what concentration of C_5H_6 will remain after 2.00 minutes?

4. Consider the following 2-step reaction mechanism involving ozone (O_3) depletion:

Elementary Step #1	$O_{3(g)}$	+	$NO_{(g)}$	---->	$NO_{2(g)}$	+	$O_{2\,(g)}$	(slow)
Elementary Step #2	$O_{(g)}$	+	$NO_{2(g)}$	----->	$NO_{\,(g)}$	+	$O_{2(g)}$	(fast)

a. Determine the overall reaction.

b. Identify any catalyst(s) and intermediate(s)

c. Was the catalyst in this reaction a homogeneous or heterogeneous catalyst?

d. Determine the rate law for the reaction.

e. Determine the "molecularity" of each elementary step
(classify each elementary step as bimolecular, unimolecular, or termolecular)

f. What is the difference between an elementary step and an overall reaction, in terms of collisions?

g. Suggest a heterogeneous catalyst for the reaction._____

5. Reaction: $2\ NO + O_2$ -----> $2\ NO_2$

A mechanism for the above reaction is shown below.
a. Show that the mechanism is consistent with the overall stoichiometry of the reaction.
b. Identify any catalysts or intermediates.

c. Which elementary step would you expect to have a higher activation energy?

d. Determine the rate law for the reaction.

e. What is the overall order of the reaction?

f. Based on the rate law, one might propose that the reaction occurred in a single elementary step. Why is this unlikely?

Step 1 (fast eqm)	NO	+	NO	<------->	N_2O_2		
Step 2 (slow)	N_2O_2	+	O_2	------->	$2\ NO_2$		

6. Y -----> Z

The concentration of Y vs time was determined at 25°C.
At 25°C, A plot of ln[Y] vs time was not linear.
A plot of 1/[Y] vs time was linear, with a slope of 0.080 L/mol-s.

a. Determine the rate law and the value of k. (Assume 25°C unless otherwise noted)
b. Will this reaction have a constant half-life? If so, calculate the half-life.
c. Make a graph showing the concentration of Y vs time.
Explain how the rate of reaction changes over time, why this happens, and how this relates to your graph.
d. If you start with a [Y] of 0.200 M, what will be the initial rate of reaction?
e. If you start with a [Y] of 0.200 M, what will be the concentration of Y after 40. seconds?
f. If you start with a [Y] of 0.200 M, what will be the rate of reaction after 40. seconds?
~~g. If the reaction has an activation energy of 42 kJ/mol, what is the value of the Arrhenius parameter A?~~
~~h. Find the rate constant at 55°C.~~

7. W ----> 2 Z at 25°C, $k = 0.000059\ s^{-1}$

Note: The rate constant for this reaction was calculated in terms of the rate of disappearance of **W**.

a. Based on the units of k, what is the overall order of the reaction?

b. Which of these plots would be linear?

ln[W] vs (1/time) ln[W] vs time [W] vs time 1/[W] vs time

c. If you start with a [W] of 0.200 Molar, what will be the molarity after 4.00 hours, if the reaction occurs at 25°C?

d. Does this reaction have a constant half life at 25°C? If so, what is the value?

e. What is the initial rate of formation of Z, if W has a starting concentration of 0.200 M? (25°C)

8. N_2O_4 + heat <----> $2\ NO_2$

Suppose that N_2O_4 and NO_2 are at equilibrium in a sealed container with a fixed volume.
a. How will the following things be affected if the temperature is increased?
Keq_____
Forward rate of rxn _____
Reverse Rate of Rxn_____
Activation energy _____

b. How will the following things be affected if a catalyst is added?
Keq_____
Forward rate of rxn _____
Reverse Rate of Rxn_____
Activation energy _____

9. $2\ NO_2$ <-----> N_2O_4 + heat
Suppose that N_2O_4 and NO_2 are at equilibrium in a sealed container with a fixed volume.
a. How will the following things be affected if the temperature is increased?
Keq_____
Forward rate of rxn _____
Reverse Rate of Rxn_____
Activation energy _____

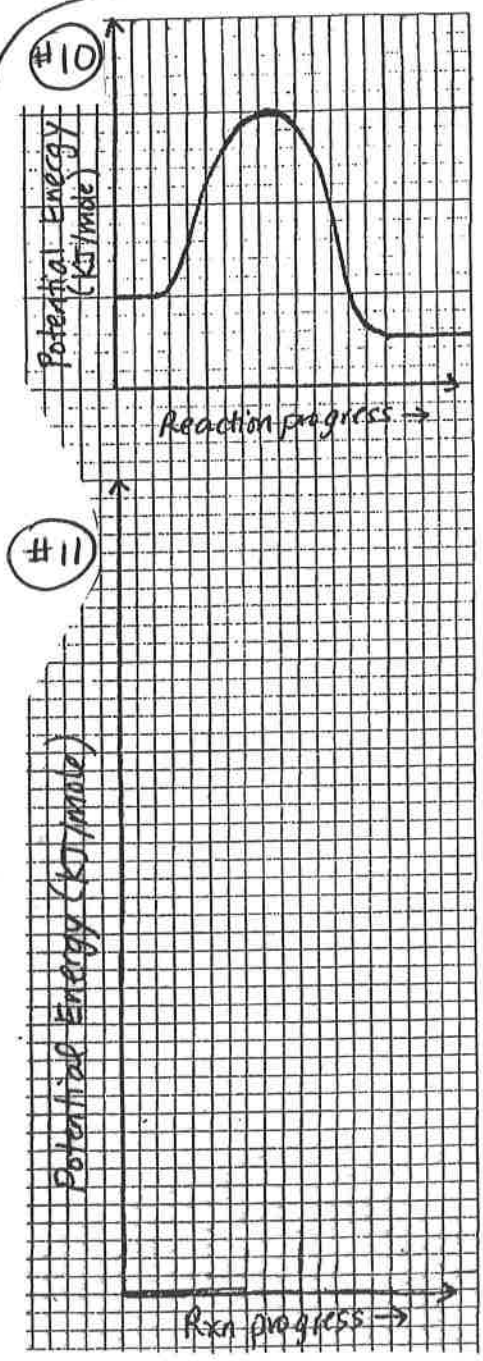
b. How will the following things be affected if a catalyst is added?
Keq_____
Forward rate of rxn _____
Reverse Rate of Rxn_____
Activation energy _____

10. Reaction for the decomposition of N_2O_5:

$$2\ N_2O_{5\,(g)} \text{ -------> } 4\ NO_{2\,(g)} + O_{2(g)}$$

The energy diagram for this reaction is shown to the right.
a. Is this reaction exothermic or endothermic?_____
b. What is the value of ΔHrxn?_____
c. Write the heat term into the equation on the correct side.
d. What is the value for Ea (Activation energy?)_____
e. Sketch the energy diagram (on the same graph) if a catalyst is added.

(for 10 and 11, use a scale of 1 square = 10 kJ)



11. Rxn: $\mathbf{CO_{2\,(g)} + NO_{(g)} \text{ ------> } CO_{(g)} + NO_{2\,(g)}}$

This reaction has an Ea = 360 kJ and a ΔHrxn of 230 kJ.

a. Is this reaction exothermic or endothermic?_____

b. Write the heat term into the equation on the correct side.

c. Sketch the energy diagram for this reaction.

d. What is the ΔH of the reverse reaction?_____

e. What is the Ea of the reverse reaction?_____

For #12, 13, and 14, determine the rate law, the value and units of k, and the overall order of the reaction.

12. 3 A + B -----> C + 2 D

Initial [A](M)	**Initial [B] (M)**	**Initial rate of formation of D (M/s)**
0.300	0.100	0.001157
0.200	0.100	0.000771
0.450	0.200	0.00694

13. C3PO + R2D2 -----> BB8 + K2SO

Initial [C3PO](M)	**Initial [R2D2] (M)**	**Initial rate of formation of BB8(M/min)**
0.100	0.100	0.013
0.900	0.200	0.078
0.400	0.100	0.026

14. 2X + Y ----> Bees?

Initial [X](M)	**Initial [Y] (M)**	**Initial rate of formation of Bees? (M/s)**
0.150	0.100	0.114
0.300	0.100	0.456
0.450	0.200	1.026

Answers!!!!

1a. $r = k[A]^1[BC_2]^2$, $k = 1.2(8)\ M^{-2}s^{-1}$ or $L^2/mol^2\text{-}s$ b. 0.00032 M/s c. 0.000069 M/s d. 0.012M/s.

2. Decrease, increase, decrease, increase

3. a. $r = k[C_5H_{10}]^2$, $k = 0.17\ M^{-1}s^{-1}$ **3e.** 0.035 M

b. As Temp increases, rate increases (see key for explanation)

c. Adding a catalyst will cause the rate to increase (see key for explan.)

d. Increasing concentration of the reactant will cause the rate to increase (see key for explan.)

4a. O3 + O ---> 2 O2 **b.** NO is a catalyst, NO2 is an intermediate. **c.** Homogeneous

d. $r = k[O3]^1[NO]^1$ **e.** Step 1 and Step 2 are each bimolecular **f**… see key **g**. Pt!

5a. The mechanism adds up to the original reaction, so, yes, it is consistent.

b. N2O2 is an intermediate. **c.** Step 2, since it has the slower rate.

d. $r = k\ [NO2]^2[O2]$ (see key for explanation/work)

e. 3rd order overall **f.** See key…termolecular collisions are rare!

6. a. $r = k[Y]^2$, $k = 0.080$ L/mol-s

b. No! Shut up! Only 1st order reactions have constant half life. This rxn is 2nd order.

c. See key **d**. initial rate = 0.0032 M/s **e.** [Y]= 0.12 Molar **f.** 0.0012 M/s

g. $A = 1.8 \times 10^6\ M^{-1}s^{-1}$ **h.** $k = 0.38\ M^{-1}s^{-1}$ at 55°C

7. a. First order (based on units of k)

b. Since it is first order, <u>ln[W] vs time</u> would be linear (with a slope of –k)

c. [W] = 0.086 M **d.** Yes! $t_{1/2}$ = 12000 seconds, or 3.3 hours **e.** 0.000024 M/s

8. a. increase, increase, increase (the fwd rate increases by a larger factor than reverse rate), no change.

b. no change, increase, increase (fwd and reverse rates increase by same factor), decrease.

9. decrease, increase, increase (the reverse rate increases by a larger factor), no change.

b. no change, increase, increase (fwd and reverse rates increase by same factor), decrease.

10. a. exo **b.** -23 kJ/mole (anywhere from -20 to -25 kJ is acceptable)

c. 100 kJ (95-100 is ok) **d.** write "+23 kJ" on the right side **e.** see key!

11. a. endo **b**. write "+230 kJ" on left side.

c. See key. **d.** ΔHreverse rxn = -230 kJ/mole **e**. Ea reverse rxn = 130 kJ/mole.

12. $r = k[A]^1[B]^2$, $k = 0.386\ M^{-2}s^{-1}$, 3rd order overall.

13. $r = k[C3PO]^{0.5}[R2D2]^1$, $k = 0.41\ M^{-0.5}min^{-1}$, the reaction is 1½ order overall.

14. $r = k[X]^2[Y]^0$ or $r = k[X]^2$. $k = 5.07\ M^{-1}s^{-1}$, 2nd order overall.