

Name: \_\_\_\_\_

(4 points)

## Chemistry 114 Third Hour Exam

**Remember- Show all work for partial credit**

1. (12 points) The reaction

$2\text{NO}(\text{g}) + \text{Cl}_2(\text{g}) \rightarrow 2\text{NOCl}(\text{g})$  was studied at  $-20^\circ\text{C}$ . The following results were obtained where  $\text{rate} = -\Delta[\text{Cl}_2]/\Delta t$

$[\text{NO}]_0$ (mole/L)	$[\text{Cl}_2]_0$ (mole/L)	Initial rate (Mole/l·min)
0.10	0.10	.29
0.10	0.16	.46
0.16	0.16	1.06

What is the order of the reaction with respect to  $[\text{NO}]$ ,  $[\text{Cl}_2]$ , and the  $k$  of the reaction?

$$\frac{\text{rate}_2}{\text{rate}_1} = \frac{.46}{.29} = \frac{k[.10]^x[.16]^y}{k[.10]^x[.10]^y}$$

$$1.59 = \frac{[.16]^y}{[.10]^y} = \left(\frac{.16}{.10}\right)^y = 1.6^y; y \approx \mathbf{1}$$

$$\frac{\text{rate}_3}{\text{rate}_2} = \frac{1.06}{.46} = \frac{k[.16]^x[.16]^1}{k[.10]^x[.16]^1}$$

$$2.304 = \frac{[.16]^x}{[.10]^x} = \left(\frac{.16}{.10}\right)^x = 1.6^x$$

$$\log(2.304) = x \log(1.6)$$

$$.362 = x(.204); x = .362/.204 = \mathbf{x = 1.77}$$

$$1.06 = k(.16)^{1.77} (.16)^1$$

$$k = \frac{1.06}{.16^{1.77} (.16)} = \mathbf{170}$$

2. (12 points) Define the following terms:

catalyst - A substance that increases the rate of a reaction, but is not consumed in a reaction

activation energy - The minimum energy needed before a chemical reaction can occur

reaction mechanism - A series of elementary steps that: 1.) Sums to equal the stoichiometric equation of a reaction and 2.) Matches the experimental kinetics of a reaction

molecularity - The number of molecules involved in determining the rate of an elementary step

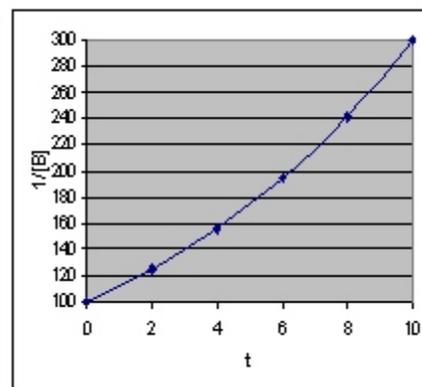
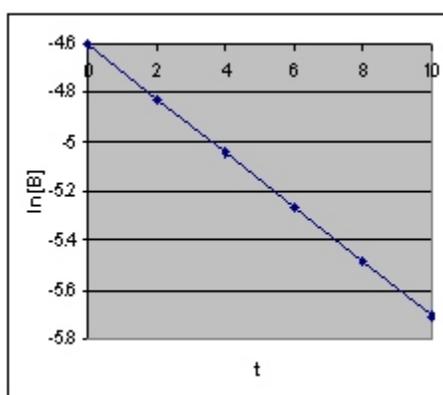
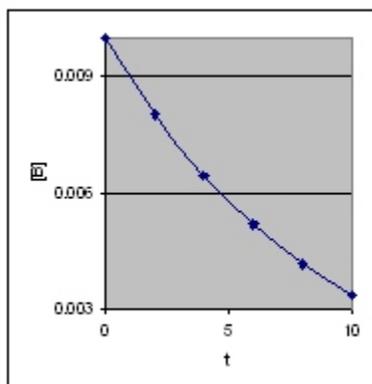
unimolecular reaction - A reaction where there is no collision, molecule just reacts by itself

Arrhenius equation -  $\text{rate} = zpe^{-E_a/RT}$

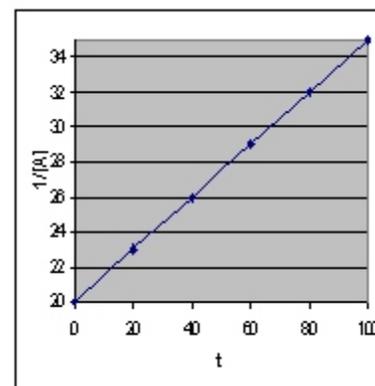
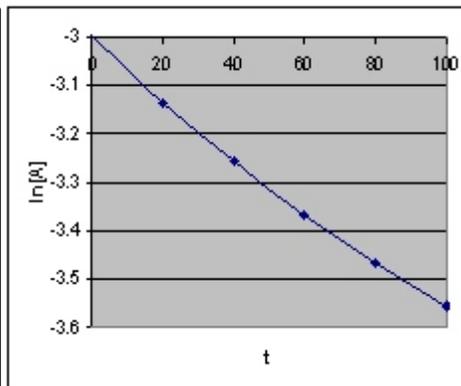
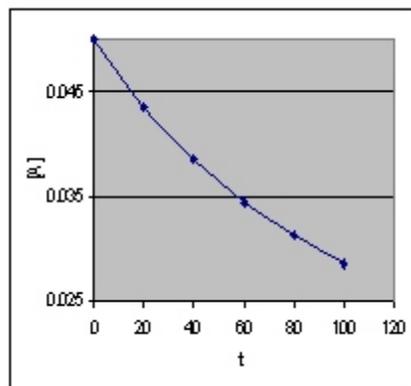
3. (12 points) The reaction

$2A + 3B \rightarrow 2C$  was studied under two conditions and the following plots were made from the data.

$[A]=1M$ ,  $[B] = .01M$



$[A]=.05M$ ,  $[B] = 2M$



What is the order of this reaction with respect to A?

Note this is the second set of plots.... 2<sup>nd</sup> order

What is the order of this reaction with respect to B?

Note this is the first set of plots ... 1<sup>st</sup> order

Write the rate expression for this reaction. (Do not try to solve for k)

$$\text{rate} = k [A]^2[B]^1$$

4. (12 points) I have a reaction that has a half-life of 20 minutes when the concentration of reactant is .75 M

A. What is the k of the reaction if the reaction is zero order?

$$T_{1/2} = [A_0]/2K; K = [A_0]/2T_{1/2} = .75/(2 \times 20) = .01875 \text{ mol}/(\text{liter} \cdot \text{min})$$

B. What is the K of the reaction if the reaction is first order?

$$T_{1/2} = .693/K; K = .693/T_{1/2} = .693/20 = .035 \text{ min}^{-1}$$

C. What is the K of the reaction if the reaction is second order?

$$T_{1/2} = 1/([A_0]K); K = 1/([A_0]T_{1/2}) = 1/(.75 \times 20) = .667 \text{ liters}/(\text{mol} \cdot \text{min})$$

5. (12 points)

The collision theory of kinetics says that the rate of a reaction is given by the equation:

$$\text{rate}(k) = zpe^{-E_a/RT}$$

What are each of the terms z,p,E<sub>a</sub>, R and T?

Z = frequency of collisions

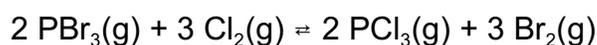
p = orientation factor (is collision properly aligned)

E<sub>a</sub> = activation energy

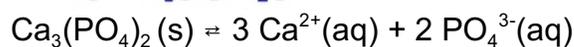
R = Gas constant in l·atm/K·mol

T = Temperature (in K)

6. (12 points) Write equilibrium expressions for the following reactions:

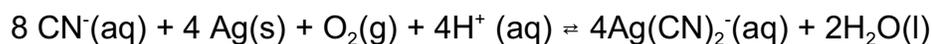


$$K = \frac{[\text{PCl}_3]^2 [\text{Br}_2]^3}{[\text{PBr}_3]^2 [\text{Cl}_2]^3}$$



$$K = [\text{Ca}^{2+}]^3 [\text{PO}_4^{3-}]^2$$

(The solid dropped out)



$$K = \frac{[\text{Ag}(\text{CN})_2^-]^4}{[\text{CN}^-]^8 P_{\text{O}_2} [\text{H}^+]^4}$$

The solid and the liquid drop out, the gas concentration is expressed as a partial pressure.

7. (12 points) The reaction  $2\text{NOCl(g)} \rightleftharpoons 2\text{NO(g)} + \text{Cl}_2\text{(g)}$  has a  $K_c = 1.6 \times 10^{-5}$

What is  $K_c$  for the reaction  $2\text{NO(g)} + \text{Cl}_2\text{(g)} \rightleftharpoons 2\text{NOCl(g)}$

$$\text{Reverse of original equation so } K = 1/K_{\text{org}} = 1/1.6 \times 10^{-5} = 62500$$

What is  $K_c$  for the reaction  $\text{NO(g)} + \frac{1}{2} \text{Cl}_2\text{(g)} \rightleftharpoons \text{NOCl(g)}$

$$\text{This is the above equation multiplied by } \frac{1}{2} \text{ so } K = (K_{\text{org}})^{1/2} = 62500^{1/2} = 250$$

What is  $K_p$  for the reaction  $4\text{NOCl(g)} \rightleftharpoons 4\text{NO(g)} + 2\text{Cl}_2\text{(g)}$   
( $T=25^\circ\text{C}$ )

First this is the original equation x2 so

$$K = K^2 = 2.56 \times 10^{-10}$$

Now do conversion from  $K_c$  to  $K_p$

$$\begin{aligned} K_p &= K_c(RT)^{\Delta n}; \Delta n = (4+2)-4 = 2 \\ &= 2.56 \times 10^{-10} (.08206 \times 298)^2 \\ &= 1.53 \times 10^{-7} \end{aligned}$$

8. (12 points) The solubility of  $\text{PbCl}_2$  is described by the equation  
 $\text{PbCl}_2\text{(s)} \rightleftharpoons \text{Pb}^{2+}\text{(aq)} + 2\text{Cl}^-\text{(aq)}$

A. Write the equilibrium expression for this reaction:

$$K = [\text{Pb}^{2+}][\text{Cl}^-]^2$$

B. The above reaction has an equilibrium constant of  $1.6 \times 10^{-5}$ . I have a solution that is supposed to contain 1 mM  $\text{Pb}^{2+}$ , 5 mM  $\text{Cl}^-$  and some solid  $\text{PbCl}_2$ . Is this solution at equilibrium?

$$\begin{aligned} 1\text{mM} &= .001\text{M}, 5\text{mM} = .005\text{M} \\ Q &= .001 \times .005^2 = 2.5 \times 10^{-8} \\ Q &\neq K, \text{ so not at equilibrium} \end{aligned}$$

C. If the reaction is not at equilibrium, what side of the reaction will it move toward? Will some solid dissolve to make more ions, or will some of the ions combine to make more solid?

$$Q \ll K, \text{ so not enough products, so solid will dissolve to make more ions}$$