Chemistry 1212 Name KEY
Thursday March 5, 2020
Exam #2

Write very clearly and **show all of your work** for partial credit. A list of equations and constants as well as a periodic table are on the last two pages of your exam.

1.(20 points) Fill in the space with the correct response.

(a) Write the equilibrium expression for: $2KClO_{3(s)} \leftrightarrow 3O_{2(g)} + 2KCl_{(s)}$ $\boxed{K_c = \left[O_{2(g)}\right]^3}$

(b) Is $K_p = K_c$ for the reaction above? Yes or No

$\boxed{No}$

(c) If the half-life for a first order reaction is 410s and $[A]_0 = 1.00$ M what is k?

$$t_{1/2} = \frac{0.693}{k} \rightarrow 4.1\times10^{2}\,s = \frac{0.693}{k} \rightarrow \boxed{k = 1.7\times10^{-3}\,s^{-1}}$$

(d) What are the units for the rate constant, k, if the reaction is 21st order?

$\boxed{M^{-20}s^{-1}}$

(e) How is the rate of consumption of O_2 related to the rate of production of NO?

$$4NH_{3(g)} + 5O_{2(g)} \rightarrow 4NO_{(g)} + 6H_2O_{(g)}$$

$$\boxed{-\frac{1}{5}\frac{\Delta[O_2]}{\Delta t} = \frac{1}{4}\frac{\Delta[NO]}{\Delta t}}$$

(f) What is the order of the reaction if you get a linear plot from ln[concentration] versus time? $\boxed{1^{st}}$

(g) How does K_c change if we multiple it by the chemical reaction by 4? $\boxed{K_c' = K_c^4}$

(h) What is the molecularity of an elementary step which contains one reactant? $\boxed{\text{unimolecular}}$

(i) Circle the correct response. Will the rate determining step have a $\boxed{\text{bigger}}$ or smaller peak in the reaction profile?

(j) Circle the correct response. If the reaction must go in the reverse direction to reach equilibrium then Q is either: $\boxed{\text{greater than}}$, less than, or equal to K.

2. (20 points) The following data were obtained for the reaction:

$$2NO_{(g)} + Cl_{2(g)} \rightarrow 2NOCl_{(g)}$$

[NO] (mol/L)	[Cl_2] (mol/L)	Initial Rate (mol/L·s)
0.13	0.20	0.010
0.26	0.20	0.040
0.13	0.10	0.0050

(a) Determine the rate law. Show your work.

Comparison between experiments 1 & 2

$$\frac{rate_1}{rate_2} = \frac{0.010}{0.040} = \frac{\cancel{k}[NO]_1^m[Cl_2]_1^n}{\cancel{k}[NO]_2^m[Cl_2]_2^n} = \left(\frac{0.13}{0.26}\right)^m \cancel{\left(\frac{0.20}{0.20}\right)^n} \quad (3pts)$$

$$\frac{1}{4} = \left(\frac{1}{2}\right)^m \rightarrow m = 2$$

Comparison between experiments 1 & 3

$$\frac{rate_1}{rate_3} = \frac{0.010}{0.0050} = \frac{\cancel{k}[NO]_1^2[Cl_2]_1^n}{\cancel{k}[NO]_3^2[Cl_2]_3^n} = \cancel{\left(\frac{0.13}{0.13}\right)^2} \left(\frac{0.20}{0.10}\right)^n \quad (3pts)$$

$$2 = (2)^n \rightarrow n = 1$$

$$\boxed{rate = k[NO]^2[Cl_2]} \quad (2pts)$$

(b) What is the overall order of the reaction?

$$2 + 1 = \boxed{3} \quad (2pts)$$

(c) Determine the rate constant (with correct units).

$$rate = k[NO]^2[Cl_2]$$

$$0.010\frac{mol}{L \cdot s} = k\left[0.13\frac{mol}{L}\right]^2\left[0.20\frac{mol}{L}\right] \rightarrow k = \boxed{3.0\frac{L^2}{mol^2 \cdot s}} \quad (5pts)$$

(d) What would be the initial rate for an experiment when both reactants are 0.12<u>M</u>?

$$rate = 3.0\frac{L^2}{mol^2 \cdot s}[NO]^2[O_2]$$

$$rate = 3.0\frac{L^2}{mol^2 \cdot s}\left[0.12\frac{mol}{L}\right]^2\left[0.12\frac{mol}{L}\right] = \boxed{0.0052\frac{mol}{L \cdot s}} \quad (5pts)$$

3. (30 points) For the mechanism below:

$$step\,1: A \rightarrow B + C\ (fast)$$
$$step\ 2: B + C \rightarrow D + B + E\ (slow)$$
$$step\ 3: D + C \rightarrow 2B(\ fast)$$

a. write the rate law for the elementary steps (6 points)

$$step\,1: rate_1 = k_1[A]$$
$$step\ 2: rate_2 = k_2[B][C]$$
$$step\ 3: rate_3 = k_3[D][C]$$

b. determine the molecularity of each elementary step (3 points)

$$step\,1: unimolecular$$
$$step\ 2: bimolecular$$
$$step\ 3: bimolecular$$

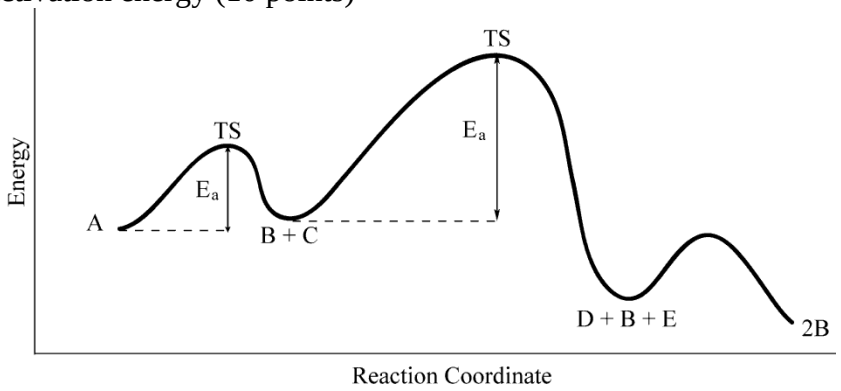
c. determine the rate law for the reaction (7 points)

$$rate_1 = k_1[A] = k_{-1}[B][C] \quad 3pts$$
$$rate_1 = [B][C] = \frac{k_1}{k_{-1}}[A] \quad 1pt$$
$$rate_2 = k_2[B][C] = \frac{k_2 k_1}{k_{-1}}[A] \rightarrow rate = K[A] \quad 3pts$$

d. identify the reaction intermediate(s). (4 points)

$$\boxed{C\ \&\ D}$$

e. draw the reaction profile indicating the location of each species, transition state, and activation energy (10 points)



2 pts for axes labels, 4 pts for species labels, 2 pts for TS, 2pts for $E_{a1}<E_{a2}$, 2pts for plot

4. (16 points) At 1400K, $K_c = 2.5 \times 10^{-3}$ for the reaction below. A 10.0 L reaction vessel at 1400K contains 2.0 mol of CH_4, 3.0 mol of CS_2, 3.0 mol of H_2, and 4.0 mol of H_2S. Is the reaction mixture at equilibrium? If not, in which direction will the reaction proceed to reach equilibrium? What is the K_p?

$$CH_{4(g)} + 2H_2S_{(g)} \leftrightarrow CS_{2(g)} + 4H_{2(g)}$$

$$Q = \frac{[CS_2][H_2]^4}{[CH_4][H_2S]^2} \quad (2\,pts)$$

$$[CH_4] = \frac{2.0\ mol}{10.0\ L} = 0.20M \quad [H_2] = 0.30M \quad [C_2S] = 0.30M \quad [H_2S] = 0.40M \quad (3\,pts)$$

$$Q = \frac{0.30^5}{0.20 \times 0.40^2} = 0.0759 > 0.0025 \quad (2\,pts)$$

$Q > K \therefore$ rxn proceeds toward reactants/reverse/to the left $(3\,pts)$

$K_p = K_c(RT)^{\Delta n}$ $(1pt)$ $\Delta n = 5 - 3 = 2$ $(1pt)$

$K_p = K_c(RT)^{\Delta n} = 2.5 \times 10^{-3}\left(0.0821 \frac{L \cdot atm}{mol \cdot K} \times 1400K\right)^2 = \boxed{33}$ $(3\,pts)$

5. Sum14 (14 points) Does the amount of chlorine gas increase, decrease, or remain the same for the following changes? Like inclass exercises

$$2NO_{(g)} + Cl_{2(g)} \leftrightarrow 2NOCl_{(g)} \quad \Delta H^\circ = -65\,{}^{kJ}/_{mol}$$

(a.) T is increased — *increase*

(b.) V is decreased — *decrease*

(c.) Neon gas is added — *remain the same*

(d.) Catalyst is removed — *remain the same*

(e.) Nitrogen dioxide gas is removed — *remain the same*

(f.) P is decreased — *increase*

(g.) Nitrogen oxide gas is added — *decrease*