

Name Key (print) Name \_\_\_\_\_ (sign)

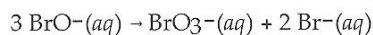
Please show work for partial credit & full credit on the Short Answer Questions. Multiple choice questions have no partial credit. Please write anything you want graded legibly. If you run out of space, continue on the empty back pages but clearly label where the remaining answers can be found. (Please count your exam pages and make sure there are ## pages) I prefer that you print the test and scan in the completed Test. However it is OK to just give multiple choice number with the correct letter and to just give short answer number on a blank sheet of paper & cell phone photo. In either case you have 2 hours 15 minutes from the time that you open the emailed test until you email the completed test back to me. This test is Open Notes and Open Book but NOT open another person.

(M = moles solute / L solution)  $[R = 0.08206 \text{ L atm}/(\text{mol K})]$   $K_p = K_c(RT)^{\Delta n}$

**MULTIPLE CHOICE. Choose the one best alternative.**

$\frac{1}{[A]}_t = kt + \frac{1}{[A]_0}$

1) A plot of  $1/[\text{BrO}^-]$  vs time is linear for the reaction:

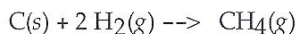


1) C

What is the order of the reaction with respect to the hypobromite ion,  $\text{BrO}^-$ ?

- A) 0                      B) 1                      C) 2                      D) 3

2) For the overall reaction shown below, what statement is correct about the rate law ?



2) B

- A) The rate law is unimolecular.                      B) The rate law cannot be determined.  
 C) The rate law is termolecular.                      D) The rate law is bimolecular.

3) Which one of the following statements does **not** describe the equilibrium state?

- A) Equilibrium is dynamic and there is no net conversion to reactants and products.  
 B) The rate of the forward reaction is equal to the rate of the reverse reaction.  
 C) The concentration of the reactants is equal to the concentration of the products.  
 D) The concentration of the reactants and products reach a constant level.

3) C

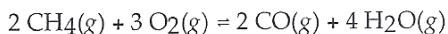
4) Which general rate law below corresponds to an elementary bimolecular reaction?

- A) Rate =  $k[A][B]^2$  *ter molecular*                      B) Rate =  $k[B]$  *uni molecular*  
 C) Rate =  $k[A]^2$                       D) Rate =  $k[A][B][C][D]$

4) C

5) Write the equilibrium equation for the reverse reaction:

5) D



A)  $K_p' = \frac{2[\text{PCH}_4] + 3[\text{PO}_2]}{2[\text{PCO}] + 4[\text{PH}_2\text{O}]}$

B)  $K_p' = \frac{[\text{PCO}]^2 [\text{PH}_2\text{O}]^4}{[\text{PCH}_4]^2 [\text{PO}_2]^3}$

C)  $K_p' = \frac{2[\text{PCO}] + 4[\text{PH}_2\text{O}]}{2[\text{PCH}_4] + 3[\text{PO}_2]}$

D)  $K_p' = \frac{[\text{PCH}_4]^2 [\text{PO}_2]^3}{[\text{PCO}]^2 [\text{PH}_2\text{O}]^4}$

6) For the reaction,  $\text{A}(\text{g}) + 2 \text{B}(\text{g}) = 2 \text{C}(\text{g})$ ,  $K_c = 5.00 \times 10^{10}$  at  $25^\circ\text{C}$ . Which of the following statements is true?

6) A

A) The concentration of the products is greater than the concentration of the reactants.

B)  $\Delta n = +1$

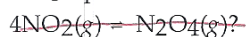
$(2 - 3 - 2 = -1)$

C) The reaction is favored in the reverse direction.

D) The value of  $K_p$  will be larger than the value for  $K_c$ .

7) If  $K_c$  equals 0.110 at  $25^\circ\text{C}$  for the reaction:  $\text{N}_2\text{O}_4(\text{g}) = 2 \text{NO}_2(\text{g})$ , what is  $K_c$  for the reaction:

7) C

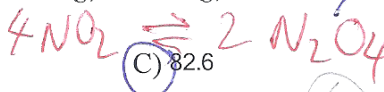


A) 7.5

B) 0.11

C) 82.6

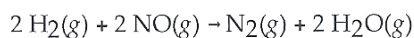
D)  $1.3 \times 10^{-3}$



$(\frac{1}{0.110})^2$

8) What is true about the relationship of  $K_p$  and  $K_c$  for the reaction:

8) B



A)  $K_p = K_c$

B)  $K_p < K_c$

C)  $K_p > K_c$

D)  $K_p$  and  $K_c$  are not related.

$\Delta n = 3 - 4 = -1$

$K_p = K_c (RT)^{\Delta n}$   
Kelvin

9) The **slowest** step in a reaction mechanism is called the \_\_\_\_\_ step.

9) D

A) termination

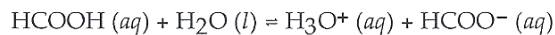
B) elementary

C) rate law

D) rate-determining

10) What is the equilibrium equation for the dissociation of formic acid in water?

10) C



A)  $K_c = \frac{[\text{H}_3\text{O}^+][\text{HCOO}^-]}{[\text{HCOOH}][\text{H}_2\text{O}]}$

B)  $K_c = \frac{[\text{HCOOH}]}{[\text{H}_3\text{O}^+][\text{HCOO}^-]}$

C)  $K_c = \frac{[\text{H}_3\text{O}^+][\text{HCOO}^-]}{[\text{HCOOH}]}$

D)  $K_c = \frac{[\text{HCOOH}][\text{H}_2\text{O}]}{[\text{H}_3\text{O}^+][\text{HCOO}^-]}$

11) Which change in the system will drive equilibrium to the left in the reaction below?

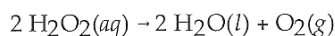
11) D



- A) increase the amount of  $\text{N}_2\text{O}_5$       B) decrease the amount of  $\text{NO}_2$   
C) decrease the amount of  $\text{NO}_3$       D) decrease the amount of  $\text{N}_2\text{O}_5$  (g)

12) The half life of the reaction shown below is found not to depend on the concentration of  $\text{H}_2\text{O}_2(\text{aq})$ .

12) B

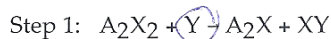


What is the order of this reaction?

- A) zeroth      B) first      C) second      D) third

13). An aqueous reaction occurs by a two-step mechanism, shown below.

13) B

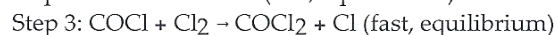
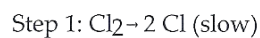


What is the catalyst in this reaction?

- A)  $\text{X}_2$       B)  $\text{Y}$       C)  $\text{A}_2\text{X}_2$       D)  $\text{XY}$

14) A three-step mechanism has been suggested for the formation of carbonyl chloride:

14) C



What is the molecularity of the rate-determining step?

- A) termolecular      B) bimolecular      C) unimolecular      D) none of these

15) Using the method of initial rates for the reaction  $\text{A} \rightarrow \text{B}$ , if the initial concentration of A is doubled and the rate of reaction doubles, what is the order of reaction with respect to A?

15) B

- A) fourth      B) first      C) second      D) zeroth

16) A catalyst increases the rate of a reaction by providing a different reaction pathway that

16) A

- A) lowers only the activation energy.  
B) raises only the energy of the products.  
C) lowers only the energy of the reactants and products.  
D) All of these are affected by the presence of a catalyst.

Part II: Short Answers Please show work on all questions for partial credit even on questions which do not specify. (40 total pts)

1. Given the following reaction experimental data, what is value of m? Show work. (10 pts)



Expt	[NO] (M)
1	0.0125
2	0.0125
3	0.0250

Cl <sub>2</sub>
0.0255
0.0510
0.0255

rate
$2.27 \times 10^{-5}$
$4.55 \times 10^{-5}$
$9.08 \times 10^{-5}$

$$\frac{9.08 \times 10^{-5}}{2.27 \times 10^{-5}} = \frac{k [0.0250]^m [1]^n}{k [0.0125]^m [1]^n}$$

5 pts

$$4 = \left[ \frac{0.0250}{0.0125} \right]^m (1)$$

$$4 = (2)^m \quad \text{5 pts}$$

$$m = 2$$

2 a. For the reaction given below, the reaction starts by having 2.57 M CH<sub>4</sub> and 1.78 M H<sub>2</sub>O (and no product) show the ICE table. (8 pts)

	CH <sub>4</sub> (g)	+ 2 H <sub>2</sub> O (g)	→	CO <sub>2</sub> (g)	+ 4 H <sub>2</sub> (g)
I	2.57	1.78		0	0
C	-x	-2x		+x	+4x
E	2.57-x	1.78-2x		+x	+4x

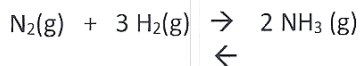
1 pt each (for I, C, E rows)  
1/2 pt each (for stoichiometric coefficients in C and E rows)

b. If K<sub>c</sub> = 7.8 × 10<sup>5</sup> for the above reaction, give the equilibrium expression based on the ICE table. (Do not solve for equilibrium concentrations of CH<sub>4</sub>.) (7 pts)

$$7.8 \times 10^5 = \frac{(x)(4x)^4}{(2.57-x)(1.78-2x)^2}$$

1 pt (for K<sub>c</sub>)  
1 pt (for x)  
2 pt (for stoichiometric coefficients)

3. For the reaction:



At the start of the reaction,  $0.0711 \text{ M N}_2$ ,  $9.17 \times 10^{-3} \text{ M H}_2$  and  $1.83 \times 10^{-4} \text{ M NH}_3$  are combined.

(a) What is the equilibrium constant expression? (6 pts)

$$K = \frac{[\text{NH}_3]^2}{[\text{N}_2][\text{H}_2]^3}$$

*2 pts each*

(b) What is Q? (6 pts)

$$Q = \frac{[1.83 \times 10^{-4}]^2}{(0.0711)(9.17 \times 10^{-3})^3} =$$

*2 pts each*

(c) Does the reaction go forward to product? Explain in a few words. (3 pts)

*typo  $k_c = 1.2 \times 10^2$*

$3.35 \times 10^{-8}$

$(0.0711)(9.17 \times 10^{-3})^3$

$K_c = 1.2 \times 10^2$

$Q = 0.611$  1 pt

$Q < K_c$

0.611       $1.2 \times 10^2$

Rxn goes  $\rightarrow$

Name Key (print) Name \_\_\_\_\_ (sign)

Please show work for partial credit & full credit on the Short Answer Questions. Multiple choice questions have no partial credit. Please write anything you want graded legibly. If you run out of space, continue on the empty back pages but clearly label where the remaining answers can be found. (Please count your exam pages and make sure there are ## pages) I prefer that you print the test and scan in the completed Test. However it is OK to just give multiple choice number with the correct letter and to just give short answer number on a blank sheet of paper & cell phone photo. In either case you have 2 hours 15 minutes from the time that you open the emailed test until you email the completed test back to me. This test is Open Notes and Open Book but NOT open another person.

(M = moles solute / L solution) [R = 0.08206 L atm/(mol K)]  $K_p = K_c(RT)^{\Delta n}$

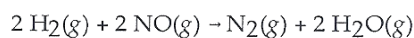
**MULTIPLE CHOICE. Choose the one best alternative.**

- 1) A catalyst increases the rate of a reaction by providing a different reaction pathway that  
 A) lowers only the energy of the reactants and products.  
 B) lowers only the activation energy. 3  
 C) raises only the energy of the products.  
 D) All of these are affected by the presence of a catalyst. 1) B

- 2) What is the overall reaction order for the reaction that has the rate law: Rate = k[H<sub>2</sub>][NO]? 2) C  
 A) zero order      B) first order      C) second order      D) third order

- 3) The slowest step in a reaction mechanism is called the \_\_\_\_\_ step. 3) B  
 A) rate law      B) rate-determining  
 C) elementary      D) termination

- 4) The reaction below is first order in H<sub>2</sub> and second order in NO. What is the rate law for this reaction? 4) C



- A) Rate = 2k[H<sub>2</sub>]<sup>1/2</sup>[NO]<sup>1/2</sup>      B) Rate = 2k[H<sub>2</sub>][NO]  
 C) Rate = k[H<sub>2</sub>][NO]<sup>2</sup>      D) Rate = k[H<sub>2</sub>]<sup>1/2</sup>[NO]

$(\frac{1}{2, 18})^2 = 4.65 \times 10^{-2}$

- 5) If K<sub>c</sub> equals 2.78 at 25°C for the reaction: N<sub>2</sub>O<sub>4</sub>(g) = 2 NO<sub>2</sub>(g), what is K<sub>c</sub> for the reaction: 5) A  
 6NO<sub>2</sub>(g) = 3 N<sub>2</sub>O<sub>4</sub>(g)? D  
 A) 4.65 × 10<sup>-2</sup>      B) 7.5      C) 751      D) 0.11

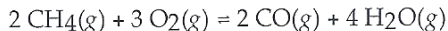
- 6) The rate constant, k, for a first-order reaction is equal to 4.2 × 10<sup>-4</sup> s<sup>-1</sup>. What is the half-life for the reaction? 6) D  
 A) 2.4 × 10<sup>3</sup> s      B) 2.9 × 10<sup>-4</sup> s      C) 1.2 × 10<sup>3</sup> s      D) 1.7 × 10<sup>3</sup> s

7) For the zeroth-order reaction:  $C \rightarrow \text{products}$ ,  $-\Delta[C]/\Delta t = k$ , which of the following graphs would be expected to give a straight line?

- A)  $1/[C]$  vs.  $t$       B)  $1/\ln[C]$  vs.  $t^2$       C)  $[C]^2$  vs.  $t^2$       **D)  $[C]$  vs.  $t$**

7) D

8) Write the equilibrium equation for the reverse reaction:



A)  $K_p = \frac{2[P_{\text{CH}_4}] + 3[P_{\text{O}_2}]}{2[P_{\text{CO}}] + 4[P_{\text{H}_2\text{O}}]}$       B)  $K_p = \frac{2[P_{\text{CO}}] + 4[P_{\text{H}_2\text{O}}]}{2[P_{\text{CH}_4}] + 3[P_{\text{O}_2}]}$

C)  $K_p = \frac{[P_{\text{CO}}]^2 [P_{\text{H}_2\text{O}}]^4}{[P_{\text{CH}_4}]^2 [P_{\text{O}_2}]^3}$       **D)  $K_p = \frac{[P_{\text{CH}_4}]^2 [P_{\text{O}_2}]^3}{[P_{\text{CO}}]^2 [P_{\text{H}_2\text{O}}]^4}$**

14

8) D

9) Which general rate law below corresponds to an elementary bimolecular reaction?

- A)  $\text{Rate} = k[A][B][C][D]$       B)  $\text{Rate} = k[A][B]^2$   
C)  $\text{Rate} = k[B]$       **D)  $\text{Rate} = k[A]^2$**

9) D

10) Which statement is true for a reaction with  $K_c$  equal to  $8.90 \times 10^{12}$ ?

- A) There are appreciable concentrations of both reactants and products.  
**B) The reaction proceeds nearly all the way to completion.**  
C) Increasing the temperature will not change the value of  $K_c$ .  
D) The reaction proceeds hardly at all towards completion.

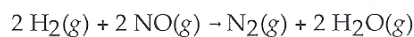
10) B

11) The elementary reaction:  $2 \text{HF} \rightarrow \text{H}_2 + \text{F}_2$ , is an example of a \_\_\_\_\_ reaction.

- A) unimolecular      B) termolecular      C) tetramolecular      **D) bimolecular**

11) D

12) What is true about the relationship of  $K_p$  and  $K_c$  for the reaction:



- A)  $K_p < K_c$**       B)  $K_p > K_c$   
C)  $K_p = K_c$       D)  $K_p$  and  $K_c$  are not related.

$\Delta n = 3 - 4 = -1$   
 $K_p = K_c [RT]^{\Delta n}$   
 $K_p < K_c$

12) A

13) What is the minimum energy barrier that must be overcome for a chemical reaction to occur?

- A) potential energy      **B) activation energy**  
C) net energy      D) rate limiting energy

8

13) B

14) Which change in the system will drive equilibrium to the left in the reaction below?

14) A



(15)

A) decrease the amount of  $\text{N}_2\text{O}_5$  (g)

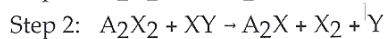
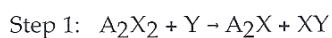
B) decrease the amount of  $\text{NO}_2$

C) increase the amount of  $\text{N}_2\text{O}_5$

D) decrease the amount of  $\text{NO}_3$

15) An aqueous reaction occurs by a two-step mechanism, shown below.

15) C



(9)

What is the catalyst in this reaction?

A)  $\text{A}_2\text{X}_2$

B)  $\text{XY}$

C)  $\text{X}_2$

D)  $\text{X}_2$

16) Which one of the following statements does **not** describe the equilibrium state?

16) B

A) The concentration of the reactants and products reach a constant level.

B) The concentration of the reactants is equal to the concentration of the products.

C) The rate of the forward reaction is equal to the rate of the reverse reaction.

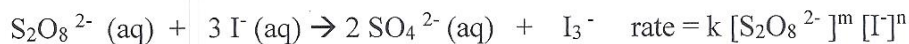
D) Equilibrium is dynamic and there is no net conversion to reactants and products.

10



Part II: Short Answers Please show work on all questions for partial credit even on questions which do not specify. (40 total pts)

1. Given the following reaction experimental data, what is value of m? Show work. (10 pts)



Expt	$\text{S}_2\text{O}_8^{2-}$	$\text{I}^-$	rate
1	0.080	0.034	$2.2 \times 10^{-4}$
2	0.080	0.017	$1.1 \times 10^{-4}$
3	0.16	0.017	$2.2 \times 10^{-4}$

$$\frac{2.2 \times 10^{-4}}{1.1 \times 10^{-4}} = \frac{k [0.16]^m [1]^n}{k [0.08]^m [1]^n}$$

*5 pts*

$$2 = (2)^m (1)^n$$

$$m = 1$$

*9 pts*

2 a. For the reaction given below, the reaction starts by having 0.0348 M  $\text{CH}_4$  and 0.234 M  $\text{H}_2\text{O}$  (and no product) show the ICE table. (8 pts)

$$\text{CH}_4 (\text{g}) + 2 \text{H}_2\text{O} (\text{g}) \rightarrow \text{CO}_2 (\text{g}) + 4 \text{H}_2 (\text{g})$$

I	0.0348	0.234	0	0
C	-x	-2x	+x	+4x
E	0.0348 - x	0.234 - 2x	+x	+4x

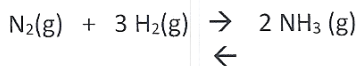
*1 pt each*  
*1/2 pt each*  
*1 pt*

b. If  $K_c = 7.98 \times 10^{-2}$  for the above reaction, give the equilibrium expression based on the ICE table. (Do not solve for equilibrium concentrations of  $\text{CH}_4$ ) (7 pts)

$$7.98 \times 10^{-2} = \frac{(x)(4x)^4}{(0.0348 - x)(0.234 - 2x)^2}$$

*1 pt* *2 pt each*

3. For the reaction:



At the start of the reaction, 0.511 M  $\text{N}_2$ , 0.0788 M  $\text{H}_2$  and 3.84 M  $\text{NH}_3$  are combined.

(a) What is the equilibrium constant expression? (6 pts)

$$K = \frac{[\text{NH}_3]^2}{[\text{N}_2][\text{H}_2]^3} \quad \text{2 pts each}$$

(b) What is Q? (6 pts)

$$Q = \frac{(3.84)^2}{(0.511)(0.0788)^3} = 2.50 \times 10^{-4} \quad \text{2 pts each}$$

(c) Does the reaction go forward to product? Explain in a few words. (3 pts)

$$Q = 5.897 \times 10^4 \quad \begin{matrix} \swarrow 4.89 \times 10^{-4} \\ \searrow 5.89 \times 10^4 \end{matrix} \quad (K_c = 1.2 \times 10^2)$$

$$K_c = 1.2 \times 10^2$$

$$5.9 \times 10^4 > 1.2 \times 10^2$$

$$Q > K_c$$

(Rxn goes toward reactant)

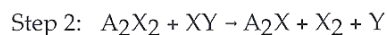
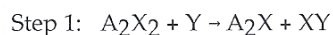
Name Keyz (print) Name \_\_\_\_\_ (sign)

Please show work for partial credit & full credit on the Short Answer Questions. Multiple choice questions have no partial credit. Please write anything you want graded legibly. If you run out of space, continue on the empty back pages but clearly label where the remaining answers can be found. (Please count your exam pages and make sure there are ## pages) I prefer that you print the test and scan in the completed Test. However it is OK to just give multiple choice number with the correct letter and to just give short answer number on a blank sheet of paper & cell phone photo. In either case you have 2 hours 15 minutes from the time that you open the emailed test until you email the completed test back to me. This test is Open Notes and Open Book but NOT open another person.

$$(M = \text{moles solute} / \text{L solution}) [R = 0.08206 \text{ L atm}/(\text{mol K})] K_p = K_c(RT)^{\Delta n}$$

**MULTIPLE CHOICE. Choose the one best alternative.**

1) An aqueous reaction occurs by a two-step mechanism, shown below.

1) D

What is the catalyst in this reaction?

A)  $A_2X_2$ 

B) XY

C)  $X_2$  D) Y

2) What is the minimum energy barrier that must be overcome for a chemical reaction to occur?

2) C

A) potential energy

B) rate limiting energy

 C) activation energy

D) net energy

3) For the zeroth-order reaction:  $C \rightarrow \text{products}$ ,  $-\Delta[C]/\Delta t = k$ , which of the following graphs would be expected to give a straight line?3) DA)  $1/[C]$  vs.  $t$ B)  $1/\ln[C]$  vs.  $t^2$ C)  $[C]^2$  vs.  $t^2$  D)  $[C]$  vs.  $t$ 

4) A catalyst increases the rate of a reaction by providing a different reaction pathway that

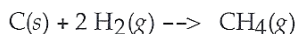
4) A A) lowers only the activation energy.

B) raises only the energy of the products.

C) lowers only the energy of the reactants and products.

D) All of these are affected by the presence of a catalyst.

5) For the overall reaction shown below, what statement is correct about the rate law ?

5) D

A) The rate law is termolecular.

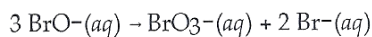
B) The rate law is bimolecular.

C) The rate law is unimolecular.

 D) The rate law cannot be determined.

6) A plot of  $1/[\text{BrO}^-]$  vs time is linear for the reaction:

6) C



What is the order of the reaction with respect to the hypobromite ion,  $\text{BrO}^-$ ?

- A) 0                      B) 1                      C) 2                      D) 3

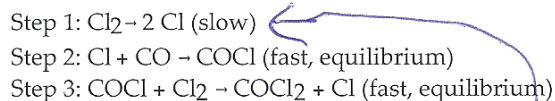
7) Which one of the following statements does **not** describe the equilibrium state?

7) B

- A) Equilibrium is dynamic and there is no net conversion to reactants and products.  
B) The concentration of the reactants is equal to the concentration of the products.  
C) The rate of the forward reaction is equal to the rate of the reverse reaction.  
D) The concentration of the reactants and products reach a constant level.

8) A three-step mechanism has been suggested for the formation of carbonyl chloride:

8) A

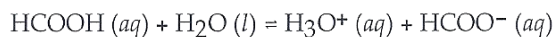


What is the molecularity of the rate-determining step?

- A) unimolecular                      B) bimolecular                      C) termolecular                      D) none of these

9) What is the equilibrium equation for the dissociation of formic acid in water?

9) C



A)  $K_c = \frac{[\text{HCOOH}] [\text{H}_2\text{O}]}{[\text{H}_3\text{O}^+] [\text{HCOO}^-]}$

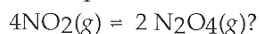
B)  $K_c = \frac{[\text{HCOOH}]}{[\text{H}_3\text{O}^+] [\text{HCOO}^-]}$

C)  $K_c = \frac{[\text{H}_3\text{O}^+] [\text{HCOO}^-]}{[\text{HCOOH}]}$

D)  $K_c = \frac{[\text{H}_3\text{O}^+] [\text{HCOO}^-]}{[\text{HCOOH}] [\text{H}_2\text{O}]}$

10) If  $K_c$  equals 0.110 at 25°C for the reaction:  $\text{N}_2\text{O}_4(g) = 2 \text{NO}_2(g)$ , what is  $K_c$  for the reaction:

10) D



- A) 7.5                      B)  $1.3 \times 10^{-3}$                       C) 0.11                      D) 82.6

11) Which general rate law below corresponds to an elementary bimolecular reaction?

11) D

A)  $\text{Rate} = k[\text{A}][\text{B}][\text{C}]$

B)  $\text{Rate} = k[\text{B}]$

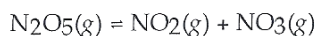
C)  $\text{Rate} = k[\text{A}] [\text{B}]^2$

D)  $\text{Rate} = k[\text{A}]^2$

$\left(\frac{1}{0.110}\right)^2 = 82.6$

12) Which change in the system will drive equilibrium to the left in the reaction below?

12) D



- A) increase the amount of  $\text{N}_2\text{O}_5$       B) decrease the amount of  $\text{NO}_2$   
C) decrease the amount of  $\text{NO}_3$       D) decrease the amount of  $\text{N}_2\text{O}_5$  (g)

13) Which general rate law below corresponds to an elementary bimolecular reaction?

13) B

- A)  $\text{Rate} = k[\text{A}][\text{B}]^2$       B)  $\text{Rate} = k[\text{A}]^2$   
C)  $\text{Rate} = k[\text{B}]$       D)  $\text{Rate} = k[\text{A}][\text{B}][\text{C}][\text{D}]$

14) If  $K_c$  equals 2.78 at  $25^\circ\text{C}$  for the reaction:  $\text{N}_2\text{O}_4(\text{g}) = 2 \text{NO}_2(\text{g})$ , what is  $K_c$  for the reaction:  
 $8\text{NO}_2(\text{g}) = 4 \text{N}_2\text{O}_4(\text{g})$ ?

14) C

- A) 0.11      B) 8.5      C) 6830      D)  $4.65 \times 10^{-2}$

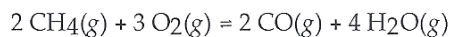
15) The slowest step in a reaction mechanism is called the \_\_\_\_\_ step.

15) A

- A) rate-determining      B) termination  
C) elementary      D) rate law

16) Write the equilibrium equation for the reverse reaction:

16) B



- A)  $K_p' = \frac{2[\text{PCH}_4] + 3[\text{PO}_2]}{2[\text{PCO}] + 4[\text{PH}_2\text{O}]}$       B)  $K_p' = \frac{[\text{PCH}_4]^2 [\text{PO}_2]^3}{[\text{PCO}]^2 [\text{PH}_2\text{O}]^4}$   
C)  $K_p' = \frac{[\text{PCO}]^2 [\text{PH}_2\text{O}]^4}{[\text{PCH}_4]^2 [\text{PO}_2]^3}$       D)  $K_p' = \frac{2[\text{PCO}] + 4[\text{PH}_2\text{O}]}{2[\text{PCH}_4] + 3[\text{PO}_2]}$

no answers

typo

$$\left(\frac{1}{K_c}\right)^4 = \left(\frac{1}{2.78}\right)^4 = 1.67 \times 10^{-2}$$

Part II: Short Answers Please show work on all questions for partial credit even on questions which do not specify. (40 total pts)

1. Given the following reaction experimental data, what is value of  $n$ ? Show work. (10 pts)



Expt	[NO] (M)	Cl <sub>2</sub>	rate
1	0.0125	0.0255	$2.27 \times 10^{-5}$
2	0.0125	0.0510	$4.55 \times 10^{-5}$
3	0.0250	0.0255	$9.08 \times 10^{-5}$

$$\frac{4.55 \times 10^{-5}}{2.27 \times 10^{-5}} = \frac{k (0.0125)^m \left(\frac{0.0510}{0.0255}\right)^n}{k (0.0125)^m (0.0255)^n}$$

$$2 = (1)^m \left(\frac{0.0510}{0.0255}\right)^n$$

$$2 = (2)^n \quad \text{5 pts}$$

$$n = 1$$

2 a. For the reaction given below, the reaction starts by having 2.57 M NO and 1.78 M Cl<sub>2</sub> and no product) show the ICE table. (8 pts)

	2 NO (g)	+ Cl <sub>2</sub> (g)	$\rightleftharpoons$	2 NOCl (g)
I	2.57M	1.78		0
C	-2x	-x		+2x
E	2.57-2x	1.78-x		2x

1 pt each

1 pt each  
(1st wrong no pts off)

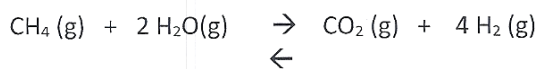
$$K_c = \frac{[\text{NOCl}]^2}{[\text{NO}]^2 [\text{Cl}_2]}$$

b. If  $K_c = 7.8 \times 10^5$  for the above reaction, give the equilibrium expression based on the ICE table. (Do not solve for equilibrium concentrations of Cl<sub>2</sub>.) (7 pts)

$$7.8 \times 10^5 = \frac{(2x)^2}{(2.57-2x)^2 (1.78-x)} \quad \text{2 pts each}$$

1 pt

3. For the reaction:



At the start of the reaction,  $7.8 \times 10^{-3} \text{ M CH}_4$ ,  $2.4 \times 10^{-2} \text{ M H}_2\text{O}$  and  $4.2 \times 10^{-3} \text{ M CO}_2$  and  $0.0036 \text{ M H}_2$  are combined.

(a) What is the equilibrium constant expression? (6 pts)

$$K = \frac{[\text{CO}_2][\text{H}_2]^4}{[\text{CH}_4][\text{H}_2\text{O}]^2}$$

(b) What is Q? (6 pts)

$$Q = \frac{(4.2 \times 10^{-3})(0.0036)^4}{(7.8 \times 10^{-3})(2.4 \times 10^{-2})^2} = \frac{7.05 \times 10^{-13}}{4.49 \times 10^{-6}}$$

$$Q = 1.57 \times 10^{-7}$$

(c) Does the reaction go forward to product?  $K = 7.82 \times 10^{10}$  Explain in a few words. (3 pts)

$$7.82 \times 10^{10} > 1.57 \times 10^{-7}$$

$K \qquad \qquad Q$

Rxn goes forward