<u>Honour Chemistry: Unit 5 Practice Test: Chemical Kinetics and Equilibrium</u>

Name: ______________________________ Date: ____________________ Block: _______

$K_P = K_c(RT)^{\Delta n}$	$R = 0.08206\ K^{-1}$

Total: 30 marks

Part A: Multiple Choice **(1 mark each)**

1. Which of the following will shift to the reactant(s) as a result of a decrease in volume?

A. $H_{2\,(g)} + Cl_{2\,(g)} \rightleftharpoons 2\ HCl_{(g)}$
B. $N_{2\,(g)} + 3\ H_{2\,(g)} \rightleftharpoons 2\ NH_{3\,(g)}$
C. $4\ Fe_{(s)} + 3\ O_{2\,(g)} \rightleftharpoons 2\ Fe_2O_{3\,(s)}$
D. $2\ SO_{3\,(g)} \rightleftharpoons 2\ SO_{2\,(g)} + O_{2\,(g)}$

2. Which statement is true for the reaction, $2\ CO_{(g)} + O_{2\,(g)} \rightleftharpoons 2\ CO_{2\,(g)}$, if its equilibrium constant equals 1.6×10^6?

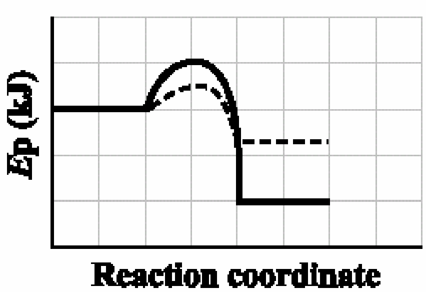
A. It essentially goes to completion at equilibrium.
B. It goes only in one direction.
C. The products will not form.
D. It takes place very rapidly.

3. One of the byproducts of the cracking process used in petroleum refineries is ethyne ($C_2H_{2\,(g)}$). In the presence of palladium catalyst, the ethyne forms ethene and ethane. This reaction is represented by the **unbalanced** equation

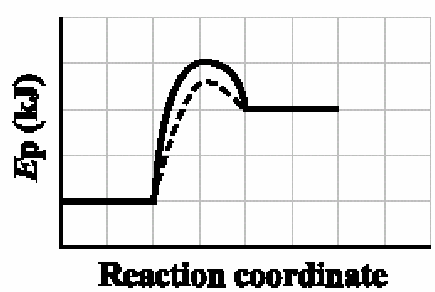
$$C_2H_{2\,(g)} + H_{2\,(g)} \rightarrow C_2H_{4\,(g)} + C_2H_{6\,(g)} + \text{energy}$$

The energy diagram that represents both the catalyzed (-----) and uncatalyzed reactions (———) is

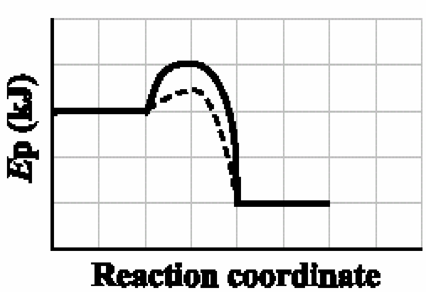
A.



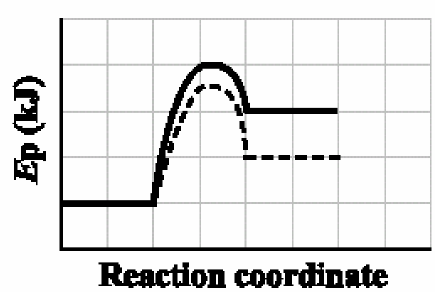
B.



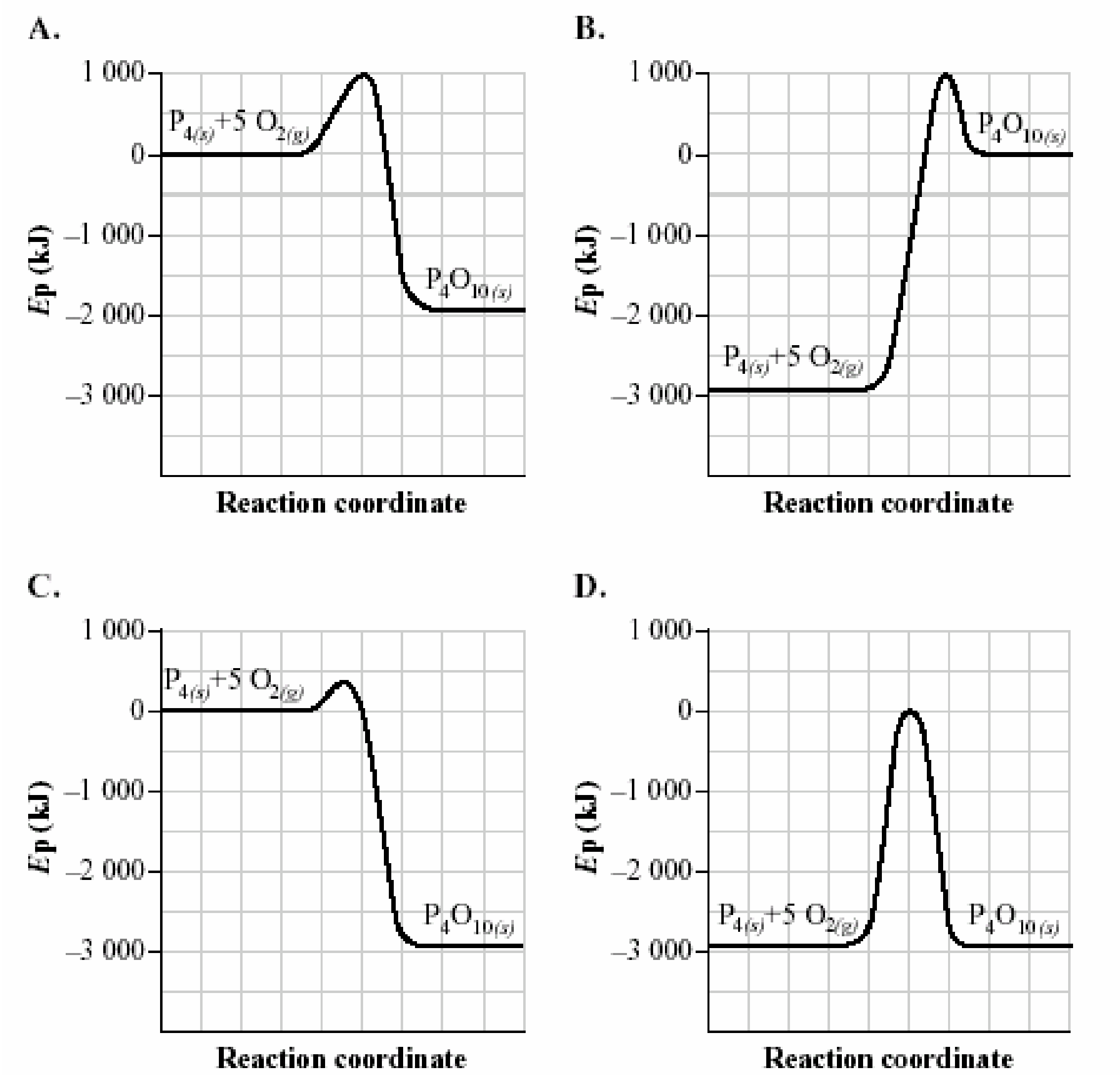
C.



D.



4. When phosphorus, $P_{4\,(s)}$, is exposed to air, it ignites spontaneously and rapidly releases 2 940 kJ/mol. Which of the following potential energy diagrams best represents this reaction?



Use the following information to answer the next question.

> The equilibrium expression for an industrial method of producing ethanol is
>
> $$K = \frac{[C_2H_5OH_{(g)}]}{[C_2H_{4(g)}][H_2O_{(g)}]}$$
>
> Under certain conditions, $K = 300.0$. At equilibrium, a 5000 L reaction vessel contains 115 mol of $C_2H_{4\,(g)}$ and 110 mol of $H_2O_{\,(g)}$.

5. Under these conditions, the equilibrium concentration of $C_2H_5OH_{\,(g)}$ is

A. 1.60×10^{-6} mol/L **B.** 0.152 mol/L **C.** 75.0 mol/L **D.** 5.92×10^{5} mol/L

Use the following information to answer the next two questions.

Coal and natural gas contain trace amounts of sulfur compounds, which when burned, may lead to acid rain pollution.

Reactions Related to Acid Rain

I	$2\ H_2S_{(g)} + 3\ O_{2\,(g)} \rightleftharpoons 2\ H_2O_{(g)} + 2\ SO_{2\,(g)}$
II	$2\ SO_{2\,(g)} + O_{2\,(g)} \rightleftharpoons 2\ SO_{3\,(g)}$
III	$SO_{2\,(g)} + 2\ H_2O_{(l)} \rightleftharpoons 2\ H_2SO_{3\,(aq)}$
IV	$2\ SO_{3\,(g)} + 2\ H_2O_{(l)} \rightleftharpoons 2\ H_2SO_{4\,(aq)}$

6. The equilibrium expression for reaction I is

A. $K = \dfrac{[H_2O_{(g)}]^2 + [SO_{2(g)}]^2}{[H_2S_{(g)}]^2 + [O_{2(g)}]^3}$

B. $K = \dfrac{[H_2S_{(g)}]^2 + [O_{2(g)}]^3}{[H_2O_{(g)}]^2 + [SO_{2(g)}]^2}$

C. $K = \dfrac{[H_2S_{(g)}]^2[O_{2(g)}]^3}{[H_2O_{(g)}]^2[SO_{2(g)}]^2}$

D. $K = \dfrac{[H_2O_{(g)}]^2[SO_{2(g)}]^2}{[H_2S_{(g)}]^2[O_{2(g)}]^3}$

7. At 900 K, the equilibrium constant for reaction II is 13.0. The equilibrium concentrations are $[SO_{2\,(g)}] = 0.361$ mol/L and $[SO_{3\,(g)}] = 0.840$ mol/L. Given this information, the calculated equilibrium concentration for $O_{2\,(g)}$ is

A. 0.179 mol/L **B.** 0.416 mol/L **C.** 2.40 mol/L **D.** 5.59 mol/L

Use the following information to answer the next question.

Some of the $SO_{2\,(g)}$ produced from the burning of coal and natural gas can react with $NO_{2\,(g)}$ in the atmosphere according to the equation

$$SO_{2\,(g)} + NO_{2\,(g)} \rightleftharpoons NO_{(g)} + SO_{3\,(g)} \qquad \Delta H = -41.9\text{ kJ}$$

8. The equilibrium concentration of $SO_{3\,(g)}$ in the reaction could be increase by

A. raising the temperature **B.** adding a catalyst **C.** adding $NO_{2\,(g)}$ **D.** removing $SO_{2\,(g)}$

Use the following information to answer the next two questions.

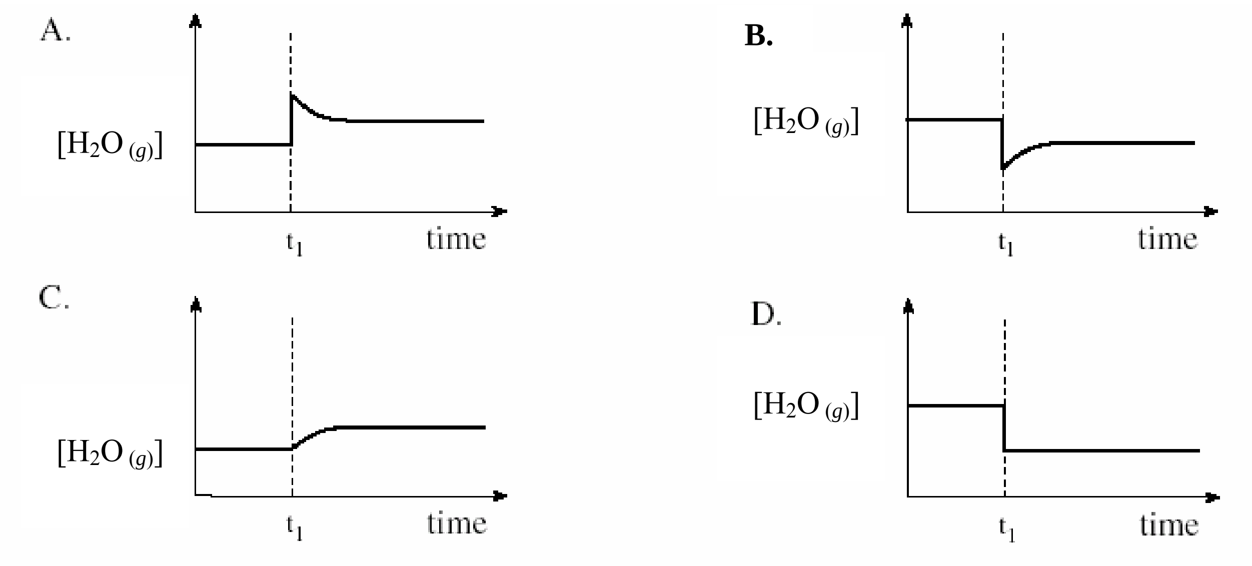
Carbon Monoxide is commonly produced by passing hydrogen gas through carbon dioxide.

$$CO_{2\,(g)} + H_{2\,(g)} \rightleftharpoons H_2O_{(g)} + CO_{(g)}$$

9. Which two stresses will each cause the equilibrium to shift to the reactants?

A. increase $[H_2]$ and increase [CO]
B. decrease $[H_2]$ and increase $[H_2O]$
C. increase $[CO_2]$ and decrease [CO]
D. decrease $[CO_2]$ and decrease $[H_2O]$

10. Which of the following graphs represents the forward reaction when $H_2O_{(g)}$ is added to the above equilibrium at time = t_1?



11. The equilibrium system $2\ NH_{3\,(g)} \rightleftharpoons N_{2\,(g)} + 3\ H_{2\,(g)}$. Initially, some NH_3 is placed into a 1.0 L container. At equilibrium, there is 0.030 mol N_2 present. What is the concentration of H_2 at equilibrium?

A. 0.010 mol/L **B.** 0.030 mol/L **C.** 0.060 mol/L **D.** 0.090 mol/L

12. Which reaction has the equilibrium expression, $K = \dfrac{[H_2O]^6[NO_2]^4}{[NH_3]^4[O_2]^7}$?

A. $4\ NH_{3\,(g)} + 7\ O_{2\,(g)} \rightleftharpoons 4\ NO_{2\,(g)} + 6\ H_2O_{(g)}$
B. $4\ NH_{3\,(g)} + 7\ O_{2\,(g)} \rightleftharpoons 4\ NO_{2\,(g)} + 6\ H_2O_{(l)}$
C. $4\ NO_{3\,(g)} + 6\ H_2O_{(l)} \rightleftharpoons 4\ NH_{3\,(g)} + 7\ O_{2\,(g)}$
D. $4\ NO_{3\,(g)} + 6\ H_2O_{(l)} \rightleftharpoons 4\ NH_{3\,(g)} + 7\ O_{2\,(g)}$

<u>Part B: Written Response</u>

1. The equilibrium system, $CH_{4\,(g)} + H_2O_{(g)} \rightleftharpoons CO_{(g)} + 3\ H_{2\,(g)}$, initially has 0.060 mol CH_4, 0.080 mol H_2O, 0.280 mol CO, and 0.740 mol H_2 in a 4.00 L container. At equilibrium, $[H_2] = 0.200$ mol/L.

(5 marks)

a. Fill in the ICE Box below and determine the equilibrium concentrations of all species.

	$CH_{4\,(g)}$ +	$H_2O_{(g)}$	$\rightleftharpoons$	$CO_{(g)}$ +	$3\ H_{2\,(g)}$
Initial					
Change					
Equilibrium					

b. Write the equilibrium expression for the above system.
c. Determine the value for the equilibrium constant.

2. One of the reason why carbon tetrachloride (CCl_4) is so harmful to the environment is because its decomposition is an equilibrium system favouring the reactant even at high temperature. The system, $CCl_{4\,(g)} \rightleftharpoons C_{(s)} + 2\ Cl_{2\,(g)}$, has an equilibrium constant, K_P, of 0.76 at 700 K. **(5 marks)**

   a. Write the equilibrium expression for the decomposition of $CCl_{4\,(g)}$.
   b. What are the final equilibrium pressures of all gaseous species if 3.00 atm of $CCl_{4\,(g)}$ is placed in a flask of a constant volume?
   c. Convert K_P into K_c.

3. Consider the reaction between ammonia and oxygen. **(5 marks)**

$$4\ NH_{3\,(g)} + 3\ O_{2\,(g)} \rightleftharpoons 2\ N_{2\,(g)} + 6\ H_2O_{(g)} \qquad (K_c = 1.21 \times 10^{-3} \text{ at 400. K})$$

   a. 4.00 mol of all species are placed in a 5.00 L flask. What are the final equilibrium concentrations all reactants and products?
   b. Find the K_c for $\frac{4}{3}\ NH_{3\,(g)} + O_{2\,(g)} \rightleftharpoons \frac{2}{3}\ N_{2\,(g)} + 2\ H_2O_{(g)}$

4. Given the following data at 25°C, **(3 marks)**

$$2\ NO_{(g)} \rightleftharpoons N_{2\,(g)} + O_{2\,(g)} \qquad K = 1.2 \times 10^{-30}$$
$$2\ NO_{(g)} + Br_{2\,(g)} \rightleftharpoons 2\ NOBr_{(g)} \qquad K = 81.$$

   Calculate K for the formation of one mole of NOBr from its elements in gaseous state at 25°C.

Answers

Part A: Multiple Choice

1. D **2.** A **3.** C **4.** C **5.** B **6.** D **7.** B **8.** C **9.** B **10.** A
11. D **12.** A

Part B: Written Response

1. a.

	$CH_{4\,(g)}$	+ $H_2O_{(g)}$	$\rightleftharpoons$	$CO_{(g)}$	+ $3\ H_{2\,(g)}$
Initial	$\frac{0.060 \text{ mol}}{4.00 \text{ L}}$ = **0.015 M**	$\frac{0.080 \text{ mol}}{4.00 \text{ L}}$ = **0.020 M**		$\frac{0.280 \text{ mol}}{4.00 \text{ L}}$ = **0.070 M**	$\frac{0.740 \text{ mol}}{4.00 \text{ L}}$ = **0.185 M**
Change	**– (0.005 M)**	**– (0.005 M)**		**+ (0.005 M)**	**+ (0.015 M)**
Equilibrium	**0.010 M**	**0.015 M**		**0.075 M**	0.200 M

b. $K = \dfrac{[CO][H_2]^3}{[CH_4][H_2O]}$ **c.** $K = 4.0$

2. a. $K_P = \dfrac{(P_{Cl_2})^2}{(P_{CCl_4})}$ **b.** $(P_{CCl_4})_{eq} = 2.33$ atm, and $(P_{Cl_2})_{eq} = 1.33$ atm **c.** $K_c = 0.0132$

3 a. $[NH_3]_{eq} = 1.07$ M; $[O_2]_{eq} = 1.00$ M, $[N_2]_{eq} = 0.664$ M; $[H_2O]_{eq} = 0.393$ M, **b.** $K_c' = 0.107$

4. $K = 8.2 \times 10^{15}$