Chem 104
Test 2 Practice Problems

1. Consider the equilibrium $C(s) + CO_2(g) \rightleftharpoons 2CO(g)$ at 1000 ºC.

a. Write the expression for K_c.

b. At 1000 ºC, $K_c = 1.603$ mol/L. A mixture of $C(s)$ with 0.750 mol/L $CO(g)$ and 0.500 mol/L $CO_2(g)$ is found at this temperature. Does the system need to **shift right**, **shift left**, or **remain unchanged** to reach equilibrium?

c. What is the value of K_p at 1000 ºC?
[$K_p = K_c(RT)^{\Delta n}$; $R = 0.08206$ L·atm/K·mol = 8.314 J/K·mol; K = ºC + 273]

d. What is the partial pressure of $CO(g)$ in an equilibrium mixture in which the partial pressure of $CO_2(g)$ is 0.100 atm?

e. If the total pressure on the system at equilibrium is increased, will the equilibrium **shift left**, **shift right**, or **remain unchanged**?

f. For the reaction $C(s) + CO_2(g) \rightarrow 2CO(g)$, $\Delta H^\circ = +172.5$ kJ. Would raising the temperature on an equilibrium mixture $C(s) + CO_2(g) \rightleftharpoons 2CO(g)$ favor **CO(*g*) formation**, **$CO_2(g)$ formation**, or **no change in the equilibrium**?

g. At higher temperature will the value of K_c **increase**, **decrease**, or **remain the same**?

2. The reaction $2N_2O_5(g) \rightarrow 4NO_2(g) + O_2(g)$ is first order. The half-life of this reaction at 45 ºC is 21.8 min.

a. What is the rate constant, k, for this reaction at 45 ºC?

b. A one-liter vessel is filled with 0.500 mol of $N_2O_5(g)$ at 45 ºC. How much $N_2O_5(g)$ will remain after 54.5 min.?

c. A student obtains data for the concentration of $N_2O_5(g)$ over time at 100 ºC. How could she use these data to obtain the value of k at 100 ºC.

d. How could the student use her data to obtain the activation energy for the decomposition of $N_2O_5(g)$? How could she obtain a value for the collision constant, A, for the reaction?

3. For the reaction $NO(g) + O_3(g) \rightarrow NO_2(g) + O_2(g)$, $\Delta H^\circ = -200$ kJ. If the activation energy of the forward reaction is 10 kJ, what is the activation energy for the reverse reaction? Sketch a potential energy diagram for the reaction.

4. At 750 °C, $K_c = 1.30$ for the reaction

$$H_2O(g) + CO(g) \rightleftharpoons H_2(g) + CO_2(g)$$

In a one-liter vessel at 750 °C, 1.20 mol of $H_2O(g)$, 1.20 mol of $CO(g)$, 0.100 mol of $H_2(g)$ and 0.100 mol of $CO_2(g)$ are mixed. What will be the concentrations of all species when equilibrium is established?

5. At 425 °C, $K_c = 54.8$ for the equilibrium

$$H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$$

If 0.500 mol each of $H_2(g)$, $I_2(g)$, and $HI(g)$ are placed in a one-liter vessel, what will be the concentrations of all species when equilibrium is established at 425 °C?

6. The reaction $2NO(g) + Cl_2(g) \rightarrow 2NOCl(g)$ might proceed by the following mechanism:

$$NO + Cl_2 \underset{k_{-1}}{\overset{k_1}{\rightleftharpoons}} NOCl_2 \qquad \text{(fast equilibrium)}$$

$$NOCl_2 + NO \xrightarrow{k_2} 2NOCl \qquad \text{(slow)}$$

a. Write the rate law expression ***for the rate-determining step***.

b. Identify any species that are reaction intermediates.

c. Write the equilibrium expression, K_c, ***for the first step***.

d. Derive the rate law expression that should be observed experimentally if this is the correct mechanism in terms of the observable concentration(s) of [NO] and/or [Cl_2]. [Hint: Use your equilibrium expression in part c to write an expression to substitute for an unobservable species that may appear in your *rate* expression for the rate-determining step.]

e. If the observed rate of the reaction is $Rate = k[NO]^2[Cl_2]$, is the proposed mechanism plausible?

7. Determine the rate law and calculate the value of the rate constant (with the appropriate units) for the reaction

$$A + B \rightarrow \text{products}$$

given the following data:

Exp.	[A]	[B]	Rate, M/s
#1	0.125	0.125	1.04×10^{-4}
#2	0.375	0.125	9.36×10^{-4}
#3	0.375	0.250	9.36×10^{-4}

8. Determine the rate law and calculate the value of the rate constant (with the appropriate units) for the reaction

$$A_2 + B + C \rightarrow AB + AC$$

given the following data:

Exp.	$[A_2]$, M	[B], M	[C], M	Rate, $M \cdot s^{-1}$
#1	0.125	0.111	0.702	1.07×10^{-3}
#2	0.500	0.111	0.702	2.14×10^{-3}
#3	0.125	0.444	0.702	4.28×10^{-3}
#4	0.125	0.444	0.351	4.28×10^{-3}

9. Determine the rate law and calculate the value of the rate constant (with the appropriate units) for the reaction

$$A + B + C \rightarrow \text{products}$$

given the following data:

Exp.	[A], M	[B], M	[C], M	Rate, $M \cdot s^{-1}$
#1	0.128	0.384	0.702	3.56×10^{-3}
#2	0.384	0.384	0.702	1.07×10^{-2}
#3	0.128	0.128	0.702	3.56×10^{-3}
#4	0.128	0.128	0.351	8.90×10^{-4}