PROBLEMS
1. Some PCl₅(g) and Cl₂(g) are mixed in a container at 200°C and the system reaches equilibrium according to the equation below. Which of the following causes an increase in the number of moles of PCl₅ at equilibrium?

PCl₅(g) + Cl₂(g) = PCl₆(g) + energy

i. Decreasing the volume of the container
ii. Raising the temperature
iii. Adding a mole of He gas at constant volume

a. i only
b. ii only
c. i and iii only
d. ii and iii only
e. i, ii, and iii

2. A student wishes to reduce the zinc ion concentration in a saturated zinc iodate solution to 1 x 10⁻⁶ M. How many moles of solid KIO₃ must be added to 1.00 L of solution? (K_{sp} = 4 x 10⁻¹⁶ for Zn(IO₃)₂ at 25°C)

a. 1 mol
b. 0.5 mol
c. 0.0001 mol
d. 4 mol
e. 2 mol

3. At constant temperature, a change in volume will NOT affect the moles of substances present in which of the following?

a. H₂(g) + I₂(g) = 2HI(g)
b. CO(g) + Cl₂(g) = COCl₂(g)
c. PCl₅(g) = PCl₃(g) + Cl₂(g)
d. N₂(g) + 3H₂(g) = 2NH₃(g)
e. CH₄(g) + CO₂(g) = 2CO(g) + 2H₂(g)

4. The equilibrium constant for the hydrolysis of C₂O₄²⁻ is best represented by which of the following?

a. K = [OH⁻][C₂O₄²⁻]/[HC₂O₄⁻]
b. K = [H₂O⁺][C₂O₄²⁻]/[HC₂O₄⁻]
c. K = [HC₂O₄⁻][H⁺]/[C₂O₄²⁻]
d. K = [C₂O₄²⁻]/[HC₂O₄⁻][OH⁻]
e. K = [C₂O₄²⁻][H⁺]/[HC₂O₄⁻][H₂O]

5. C(s) + H₂O(g) = CO(g) + H₂O(g) is endothermic. An equilibrium mixture of the reactants is placed in a sealed container at 150°C. The amount of the products may be increased by which of the following changes?

i. Increasing the temperature of the container
ii. Adding 1 mol of C(s) to the container
iii. Raising the temperature of the container

f. i only
g. i and ii
h. i only
i. ii and iii
j. iii only

6. C₂H₆(g) + 3O₂(g) = 2CO₂(g) + 2H₂O(g). An equimolar number of moles of each of the reactants are sealed in a container and allowed to come to the equilibrium shown above. At equilibrium, which of the following must be true?

i. [CO₂] must be equal to [H₂O]
ii. [CO₂] must be less than [C₂H₆]
iii. [CO₂] must be greater than [C₂H₆]

a. i and iii
b. i only
c. iii only
d. ii only
e. i and ii

7. CH₄(g) + CO₂(g) = 2CO(g) + 2H₂(g). A 1.00-L flask is filled with 0.30 mol of CH₄ and 0.40 mol of CO₂, and allowed to come to equilibrium. At equilibrium, there are 0.20 mol of CO in the flask. What is the value of K_c, the equilibrium constant, for this reaction?

a. 1.2
b. 0.027
c. 0.30
d. 0.060
e. 3.0

8. NO₂(g) = 2NO(g) + O₂(g). The above materials were sealed in a flask and allowed to come to equilibrium at a certain temperature. A small quantity of O₂(g) was added to the flask, and the mixture allowed to return to equilibrium at the same temperature. Which of the following has increased over its original equilibrium value?

a. The quantity of NO₂(g) present
b. The quantity of NO(g) present
c. The equilibrium constant, K

9. 2CH₄(g) + O₂(g) = 2CO(g) + 4H₂(g) \( \Delta H < 0 \). In order to increase the value of the equilibrium constant, K, which of the following changes must be made to the above equilibrium?

a. Increase the temperature
b. Increase the volume
c. Decrease the temperature
d. Add CO(g)
e. Add a catalyst

10. The addition of nitric acid increases the solubility of which of the following compounds?

a. KCl(s)
b. Pb(CN)₂(s)
c. Cu(NO₃)₂(s)
d. NH₄NO₃(s)
e. FeSO₄(s)

11. The K_{sp} for Mn(OH)₂ is 1.6 x 10⁻¹³. What is the molar solubility of this compound in water?

a. (4.0 x 10⁻¹⁴)³/₂
b. 1.6 x 10⁻¹⁰
c. (4.0 x 10⁻¹³)³/₂
d. (4.0 x 10⁻¹⁴)³/₂
e. 4.0 x 10⁻¹⁴
12. An aqueous solution is prepared that is initially $0.100 \, M \text{CdI}_4^{2-}$. After equilibrium is established, the solution is found to be $0.013 \, M$ in Cd$^{2+}$.

\[
\text{CdI}_4^{2-} (aq) \rightleftharpoons \text{Cd}^{2+} (aq) + 4\text{I}^- (aq)
\]

a. Derive the expression for the dissociation constant and determine the value of the constant.

b. What will be the cadmium ion concentration arising when 0.400 mol of KI is added to 1.00 L of the solution in part a?

c. A solution is prepared by mixing 0.500 L of the solution from part b and 0.500 L of $2.0 \times 10^{-5} \, M$ NaOH. Will the cadmium hydroxide, Cd(OH)$_2$, precipitate? The $K_{sp}$ for cadmium hydroxide is $2.2 \times 10^{-14}$.

d. When the initial solution is heated, the cadmium ion concentration increases. Is the equilibrium an exothermic or an endothermic process? Explain how you arrived at your conclusion.