Equilibrium Review

1. Consider the following equilibrium system:

$$2CrO_4^{2-}(aq) + 2H^+(aq) \Leftrightarrow Cr_2O_7^{2-}(aq) + H_2O(l)$$

At equilibrium the $[CrO_4^{2-}]$ remains constant even though the forward reaction continues to occur. Explain.

2a. Why are chemical equilibria referred to as dynamic?
b. How is a chemical system at equilibrium recognized?

3. State LeChatelier's Principle.

4. At equilibrium, the macroscopic properties of a system are constant. Give an example of a macroscopic property and explain why it is constant at equilibrium.

5. Consider the following equilibrium system:

$$N_2(g) + 3H_2(g) \Leftrightarrow 2NH_3(g) + \text{energy}$$

For the forward direction:
a. Explain if enthalpy is increasing or decreasing and why.
b. Explain if entropy is maximized or minimized and why.

6. Consider the following reaction:

$$N_2O_4(g) + \text{energy} \; ?\Rightarrow? \; 2NO_2(g)$$

Will this system come to equilibrium? Explain using enthalpy and entropy.

7. Consider the following equilibrium system:

$$CO(g) + 2H_2(g) \Leftrightarrow CH_3OH(g) + \text{energy}$$

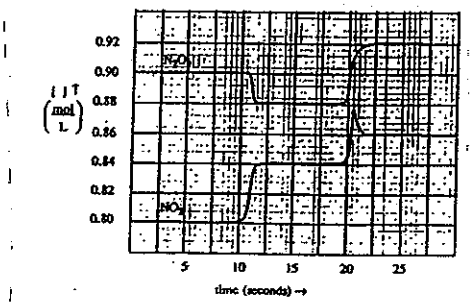
Describe how moles of CH_3OH change due to the following changes:
a. increase in temperature
b. addition of CO
c. removal of H_2
d. increase in pressure
e. addition of CH_3OH
f. removal of CH_3OH

8. Use graphs and explanations to depict how the forward and reverse rates change due to addition of CO until a new equilibrium is established (use the equilibrium from question 7).

9. Consider the following equilibrium:

$$N_2O_{4(g)} + 59kJ \Leftrightarrow 2NO_{2(g)}$$

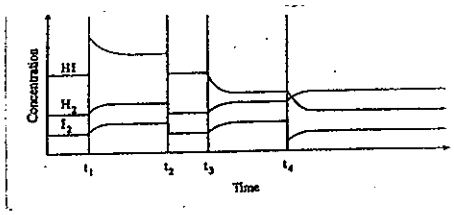
The graph below shows the $[N_2O_4]$ and the $[NO_2]$ plotted against time.



a. Calculate the Keq for the reaction at 5, 15, and 25 seconds.
b. Explain the change in conditions imposed on the system at 10s using LeChatelier's Principle. Also, support your explanation using Keq values.
c. Explain the change in condition imposed on the system at 20s using LeChatelier's Principle. Also, support your explanation using Keq values.

10. Consider the following graph for the equilibrium:

$$H_{2(g)} + I_{2(g)} \Leftrightarrow 2HI_{(g)} + 52kJ$$



Identify the imposed changes at time:

a. t_1 b. t_2 c. t_3 d. t_4

11. Consider the following equilibrium system:

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

In an experiment, 0.90 moles of NO and 0.60 moles of Cl_2 are placed into a 1.0L container and allowed to establish equilibrium. At equilibrium, [NOCl] = 0.56M. Calculate the Keq value.

12. 0.400mol of H_2 and 0.200mol of I_2 were placed in a 2.00L flask and allowed to reach equilibrium according to the reaction

$$H_{2(g)} + I_{2(g)} \Leftrightarrow 2HI_{(g)}$$

At equilibrium [HI] = 0.160 mol/L. Calculate the equilibrium constant.

13. Consider the following equilibrium:

$$2NO_{(g)} + O_{2(g)} \Leftrightarrow 2NO_{2(g)} \qquad K_{eq} = 6.45 \times 10^5$$

a) Write the K_{eq} expression.

b) Explain why the $[NO_2]$ is greater than the [NO] at equilibrium when the $[O_2]$ is 1.0 mol/L.

14. Consider the following equilibrium:

$$N_2H_{4(g)} + 2O_{2(g)} \Leftrightarrow 2NO_{(g)} + 2H_2O_{(g)}$$

More oxygen is added to the above equilibrium. After the system reestablishes equilibrium, identify the substance(s) that have a net

a) increase in concentration

b) decrease in concentration

Support your answer with an equilibrium graph tracking the concentration change.

15. Consider the following equilibrium:

$$SO_{3(g)} + NO_{(g)} \Leftrightarrow NO_{2(g)} + SO_{2(g)} \qquad K_{eq} = 0.500$$

0.100mol SO_3 and 0.100mol NO were placed in a 1.00L flask and allowed to react. Calculate $[SO_2]$ at equilibrium.

16. Consider the following equilibrium system:

$$N_{2(g)} + O_{2(g)} \Leftrightarrow 2NO_{(g)} \qquad K_{eq} = 0.0081$$

0.200mol of N_2 and 0.200mol of O_2 are placed into a 5.00L container and allowed to establish equilibrium. Calculate the concentration of each substance at equilibrium.

17. Consider the following equilibrium:

$$2NOBr_{(g)} + Br_{2(g)} \Leftrightarrow 2NOBr_{2(g)} \qquad K_{eq} = 1.0 \times 10^2$$

An unknown amount of NOBr is placed into a 2.00L container. At equilibrium, the $[Br_2]$ = 0.0400M. Calculate the moles of NOBr initially placed in the container.

18. Consider the following equilibrium:

$2HCl_{(g)} \Leftrightarrow H_{2(g)} + Cl_{2(g)}$ $\quad K_{eq} = 0.700$

Initially, unknown amounts of H_2 and Cl_2 were placed in a container. At equilibrium, [HCl] = 0.240M. Find the initial [H_2] and [Cl_2].

19. Consider the equilibrium:

$CH_{4(g)} + H_2O_{(g)} \Leftrightarrow CO_{(g)} + 3H_{2(g)}$ $\quad K_{eq} = 6.58$

A student places 0.360M CH_4, 0.0800M H_2O, 0.320M CO and 0.780M H_2 into a 1.00L container. Show by calculation whether [CH_4] increases, decreases, or stays the same.

20. Consider the following equilibrium:

$CH_{4(g)} + H_2O_{(g)} \Leftrightarrow CO_{(g)} + 3H_{2(g)}$

Keq	Temperature
1.78×10^{-3}	800°C
4.68×10^{-2}	1000°C

Is the forward reaction in this equilibrium endothermic or exothermic? Explain your answer.

21. Given the reacting system:

$H_{2(g)} + I_{2(g)} \Leftrightarrow 2HI_{(g)}$ $\quad K_{eq} = 64$

Equal moles of H_2, I_2, and HI are placed into a 1.00L container. Use calculations to determine the direction the reaction will proceed in order to reach equilibrium.