Equilibrium: Checking for Understanding & Practice Problems

Name BETH "KEY" Period _____

As a reaction is approaching equilibrium describe how the following change.

1. Reactant concentration.
   As the rxn goes to the right the reactant concentration decreases
2. Products concentration.
   As the rxn goes to the right the product concentration increases.
3. Forward reaction rate.
   The reactant concentration decreases as the rxn proceeds, therefore there are less reactant collisions causing the forward rate to decrease.
4. Reverse reaction rate.
   As the rxn proceeds, the product concentrations ↑ so more product collisions ↑ the rate of the reverse rxn.
5. What is equal at equilibrium?
   The rate of the forward rxn and the rate of the reverse rxn.
6. What is constant at equilibrium?
   The reactant and product concentrations.

Solve the following problems and be sure to show all of your work.

1. At equilibrium at 100°C, a 2.0L flask contains:

0.075 mol of PCl_5 0.050 mol of H_2O 0.750 mol Of HCl 0.500 mol of $POCl_3$

Calculate the Keq for the reaction:

$$PCl_5\,(s) + H_2O\,(g) \rightleftarrows 2HCl\,(g) + POCl_3\,(g)$$

$M = \frac{mol}{L}$

$M_{H_2O} = \frac{0.050 mol}{2.0L} = 0.025\,M$

$M_{HCl} = \frac{0.750 mol}{2.0L} = 0.38\,M$

$M_{POCl_3} = \frac{0.500 mol}{2.0L} = 0.25M$

$K_{eq} = \frac{[HCl]^2[POCl_3]}{[H_2O]}$

$K_{eq} = \frac{(0.38)^2(.25)}{(.025)} = 1.4$

Keq = 1.4

2. Keq= 798 at 25°C for the reaction: $2SO_2(g) + O_2(g) \rightleftarrows 2SO_3(g)$.

In a particular mixture at equilibrium, $[SO_2]$= 4.20 M and $[SO_3]$=11.0M. Calculate the equilibrium $[O_2]$ in this mixture at 25°C.

$$K_{eq} = \frac{[SO_3]^2}{[SO_2]^2[O_2]} \qquad [O_2] = \frac{[SO_3]^2}{K_{eq}[SO_2]^2}$$

$$[O_2] = \frac{(11.0M)^2}{(798)(4.20M)^2} = \quad [O_2] = 0.00860M$$

3. Consider the following equilibrium:

$$2\ NO_{2(g)} \rightleftarrows N_2O_{4(g)}$$

2.00 moles of NO_2 and 1.60 moles of N_2O_4 are present in a 4.00 L flask at equilibrium at 20°C. Calculate the Keq at 20°C .

$$K_{eq} = \frac{[N_2O_4]}{[NO_2]^2} \qquad M_{NO_2} = \frac{2.00mol}{4.00L} = 0.500M$$

$$M_{N_2O_4} = \frac{1.60mol}{4.00L} = 0.400M$$

$$K_{eq} = \frac{(0.400)}{(0.500)^2} = 1.60$$

Keq = 1.60

4. If at equilibrium $[H_2]$ = 0.200M and $[I_2]$ = 0.200M and Keq=55.6 at 250°C, calculate the equilibrium concentration of HI.

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

$$K_{eq} = \frac{[HI]^2}{[H_2][I_2]} \qquad [H_2][I_2]K_{eq} = [HI]^2$$

$$\sqrt{[H_2][I_2]K_{eq}} = [HI]$$

$$\sqrt{(0.200M)(0.200M)(55.6)} = \quad [HI] = 1.49\ M$$

5. 1.60 moles CO, 1.60 moles H_2O, 4.00 moles CO_2, 4.00moles H_2 are found in a 8.00L container at 690°C at equilibrium.

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

Calculate the value of the equilibrium constant.

$$K_{eq} = \frac{[CO_2][H_2]}{[H_2O][CO]} = \frac{\left(\frac{4.00}{8.00}\right)\left(\frac{4.00}{8.00}\right)}{\left(\frac{1.60}{8.00}\right)\left(\frac{1.60}{8.00}\right)} = 6.25$$

Keq = 6.25

Describe the changes that occur after each stress is applied to the equilibrium.

$$4HCl_{(g)} + O_{2(g)} \rightleftharpoons 2H_2O_{(g)} + 2Cl_{2(g)} + 98\ KJ$$

Stress	$[O_2]$	$[H_2O]$	$[HCl]$	Shifts Right or Left	Favors Products or Reactants
1. [HCl] is increased	↓	↑	↑	R	P
2. $[H_2O]$ is increased	↑	↑	↑	L	R
3. $[O_2]$ is increased	↑	↑	↓	R	P
4. Temp is increased	↑	↓	↑	L	R
5. $[H_2O]$ is decreased	↓	↓	↓	R	P
6. [HCl] is decreased	↑	↓	↓	L	R
7. $[O_2]$ is decreased	↓	↓	↑	L	R
8. Temp is decreased	↓	↑	↓	R	P
9. A catalyst is added	—	—	—	—	—

$$CaCO_{3(s)} + 170\ KJ \rightleftharpoons CaO_{(s)} + CO_{2(g)}$$

Note : Adding solids or liquids and removing solids or liquids does not shift the equilibrium. This is because you cannot change the concentration of a pure liquid or solid as they are 100% pure. It is only a concentration change that will change the # of collisions and hence shift the equilibrium.

Stress	$[CO_2]$	Shifts Right or Left	Favors Products or Reactants
1. $CaCO_3$ is added	—	—	—
2. CaO is added	—	—	—
3. CO_2 is added	↑	L	R
4. Temp is increased	↑	R	P
5. A catalyst is added	—	—	—
6. $[CO_2]$ is decreased	↓	R	P
7. Temp is increased	↑	R	P
8. CaO is removed	—	—	—

Consider the following equilibrium:

$2NO_{(g)} + Br_{2(g)} + \text{energy} \longleftrightarrow 2NOBr_{(g)}$

State what affect each of the following will have on this system in terms of shifting.

1. The volume of the vessel is increased

LEFT

2. The pressure is decreased

LEFT

3. More Br_2 is added to the system

RIGHT

4. Some NO is removed from the system

LEFT

5. A catalyst is added to the system

NO CHANGE

For the following reaction:

$N_2O_{4(g)} + 59\ KJ \rightleftharpoons 2\ NO_{2(g}$

Describe four ways of increasing the yield.

↑ TEMP ↑ $[N_2O_4]$

↓ PRESSURE ↓ $[NO_2]$

Describe three ways to increase the rate of the above reaction.

↑ TEMP

↑ $[N_2O_4]$

↑ P

ADD A CATALYST