Chemistry 122

Worksheet: Chemical Equilibrium Review

1. What main idea explains chemical equilibrium?
2. List three ways that reaction rates can be increased.
3. Define Le Chatelier's Principle.
4. How does a change in volume affect the pressure of the system?

5. For each of the following descriptions, write a chemical equation for the system at equilibrium. Communicate the position of the equilibrium with equilibrium arrows. Then write a mathematical expression of the equilibrium law for each chemical system.
   (a) The formation of ammonia (NH_3) provides a percent yield of 10.0%.
   (b) The formation of water vapor from hydrogen and oxygen is quantitative.
   (c) The reaction of carbon monoxide with water vapor to produce carbon dioxide and hydrogen has a percent yield of 67%.

6. Predict the shift in the following equilibrium system resulting from each of the following changes.

$$\mathbf{4HCl_{(g)} + O_{2(g)} \leftrightarrow 2H_2O_{(g)} + 2Cl_{2(g)} + 113kJ}$$

   (a) an increase in the temperature of the system
   (b) a decrease in the system's total pressure due to an increase in the volume of the container
   (c) an increase in the concentration of oxygen
   (d) the addition of a catalyst

7. The equilibrium constant for the reaction of nitrogen dioxide to form dinitrogen tetroxide is 5.6.

$$\mathbf{2NO_{2\,(g)} \leftrightarrow N_2O_{4(g)}}$$

   In a one-liter container, the amount of N_2O_4, at equilibrium, is 0.66 mol. What is the equilibrium concentration of NO_2?

8. Hydrogen sulfide gas decomposes into its elements and establishes an equilibrium at 1400°C.

$$\mathbf{8H_2S_{(g)} \leftrightarrow 8H_{2(g)} + S_{8(g)}}$$

A liter of this gas mixture at equilibrium contains 0.18 mol H_2S, 0.014 mol H_2, and 0.035 mol S_8. Calculate the equilibrium constant, K_{eq}, for this reaction.

9. For the equilibrium $2HI_{(g)} \leftrightarrow H_{2(g)} + I_{2(g)}$, K_{eq} = 0.905 at 60.0°C. If $[H_{2(g)}] = [I_{2(g)}]$ = 1.20 mol/L, calculate the $[HI_{(g)}]$. Is this a reactant-favoured or product-favoured reaction?

Calculate the percent reaction and write the reaction expression for the following equilibria.

10. 384 g of $S_{8(g)}$ reacts with 205 g of oxygen gas to produce 680. g of sulfur dioxide gas.

11. 12.70 g of nitrogen reacts with 6.24 g of hydrogen to produce 3.77 g of ammonia.

WORKSHEET: CHEMICAL EQUILIBRIUM REVIEW

*1. Chemical equilibrium → two processes (forward and reverse) occurring at the same rate.

*2. Reaction rates can be increased by:
1) Adding a catalyst
2) Increasing the temperature
3) Decreasing the particle size

*3. Le Chatelier's Principle → when a stress is placed on a system, the system will act to relieve the stress and re-achieve equilibrium.

*4. Changing the volume of a system will result in the opposite change of pressure.
i.e. Decrease volume, increase pressure.
Increase volume, decrease pressure

*5. a) $N_{2(g)} + 3H_{2(g)} \xrightleftharpoons{10\%} 2NH_{3(g)}$ $\quad K = \frac{[NH_{3(g)}]^2}{[N_{2(g)}][H_{2(g)}]^3}$

b) $2H_{2(g)} + O_{2(g)} \xrightleftharpoons{>99\%} 2H_2O_{(g)}$ $\quad K = \frac{[H_2O_{(g)}]^2}{[H_{2(g)}]^2[O_{2(g)}]}$

c) $CO_{(g)} + H_2O_{(g)} \xrightleftharpoons{61\%} CO_{2(g)} + H_{2(g)}$ $\quad K = \frac{[CO_{2(g)}][H_{2(g)}]}{[CO_{(g)}][H_2O_{(g)}]}$

*6. $4HCl_{(g)} + O_{2(g)} \rightleftharpoons 2H_2O_{(g)} + 2Cl_{2(g)} + 113kJ$

a) increase temperature — SHIFT LEFT
b) decrease pressure — SHIFT LEFT
c) increase $[O_{2(g)}]$ — SHIFT RIGHT
d) add a catalyst — NO CHANGE

*7. $2NO_{2(g)} \rightleftharpoons N_2O_{4(g)}$ $K = 5.6$

0.66 mol $V = 1.0 L$

? 0.66 mol/L

$$K = \frac{[N_2O_{4(g)}]}{[NO_{2(g)}]^2}$$

$$[NO_{2(g)}] = \sqrt{5.6[0.66]}$$

$$\boxed{[NO_{2(g)}] = 1.9 \text{ mol/L}}$$

*8. $8H_2S_{(g)} \rightleftharpoons 8H_{2(g)} + S_{8(g)}$ $K = ?$

0.18 mol 0.014 mol 0.035 mol $V = 1.0 L$

0.18 mol/L 0.014 mol/L 0.035 mol/L

$$K = \frac{[H_{2(g)}]^8[S_{8(g)}]}{[H_2S_{(g)}]^8}$$

$$K = \frac{[0.014]^8[0.035]}{[0.18]^8}$$

$$\boxed{K = 4.7 \times 10^{-11}}$$

*9. $2HI_{(g)} \rightleftharpoons H_{2(g)} + I_{2(g)}$ $K = 0.905$

? 1.20 mol/L 1.20 mol/L

$$K = \frac{[H_{2(g)}][I_{2(g)}]}{[HI_{(g)}]^2}$$

$$[HI_{(g)}]^2 = \frac{[H_{2(g)}][I_{2(g)}]}{K}$$

$$[HI_{(g)}] = \sqrt{\frac{[1.20][1.20]}{0.905}}$$

$$\boxed{[HI_{(g)}] = 1.26 \text{ mol/L}}$$

*10. $S_{8(g)} + 8O_{2(g)} \rightleftharpoons 8SO_{2(g)}$

init. 384g 205g

eqm. 380g

Find max. product

If S_8 is L.R.:

$384g\ S_8 \times \frac{1\ mol\ S_8}{256.48g\ S_8} \times \frac{8\ mol\ SO_2}{1\ mol\ S_8} \times \frac{64.06g\ SO_2}{1\ mol\ SO_2} = 767.28g\ SO_2$

If O_2 is L.R.

$205g\ O_2 \times \frac{1\ mol\ O_2}{32.00g\ O_2} \times \frac{8\ mol\ SO_2}{8\ mol\ O_2} \times \frac{64.06g\ SO_2}{1\ mol\ SO_2} = 410.38g\ SO_2$

∴ O_2 is L.R.

$\%\ rxn = \frac{exp}{theor.} \times 100\%$

$\%\ rxn = \frac{380g}{410.38g} \times 100\%$

$\%\ rxn = 92.6\%$

$S_{8(g)} + 8O_{2(g)} \overset{92.6\%}{\rightleftharpoons} 8SO_{2(g)}$

*11.

	$N_{2(g)}$ +	$3H_{2(g)}$ $\longrightarrow$	$2NH_{3(g)}$
init.	12.70g	6.24g	
eqm.			3.77g

Find max. product.

If N_2 is L.R.:

$$12.70g\ N_2 \times \frac{1\ mol\ N_2}{28.02g\ N_2} \times \frac{2\ mol\ NH_3}{1\ mol\ N_2} \times \frac{17.04\ g\ NH_3}{1\ mol\ NH_3} = \boxed{15.45g\ NH_3}$$

If H_2 is. L.R.:

$$6.24g\ H_2 \times \frac{1mol\ H_2}{2.02g\ H_2} \times \frac{2\ mol\ NH_3}{3\ mol\ H_2} \times \frac{17.04\ g\ NH_3}{1\ mol\ NH_3} = 35.09g\ NH_3$$

∴ N_2 is L.R.

$$\%\ rxn = \frac{exp.}{theor.} \times 100\%$$

$$\%\ rxn = \frac{3.77g}{15.45g} \times 100\%$$

$$\boxed{\%\ rxn = 24.4\%}$$

$$\boxed{N_{2(g)} + 3H_{2(g)} \overset{24.4\%}{\rightleftharpoons} 2NH_{3(g)}}$$