

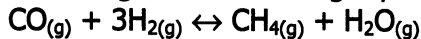
# AP Chemistry Equilibrium Worksheet

apchemequiw0809.doc

Name: Key

Date: \_\_\_\_\_ Period: \_\_\_\_\_

1. Carbon monoxide and hydrogen react according to the following equation:



When 1.000 mol CO and 3.000 mol H<sub>2</sub> are placed in a 10.00L vessel at 927°C (1200.K) and allowed to come to equilibrium, the mixture is found to contain 0.387 mol H<sub>2</sub>O. What is the molar composition of the equilibrium mixture? That is, how many moles of each substance are present?

0.387 mol H<sub>2</sub>O      0.387 mol CH<sub>4</sub>

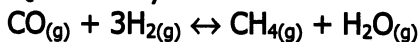
$$\text{mol CO} = 1.000 - 0.387 = .613 \text{ mol CO}$$

$$\text{mol H}_2 = 3.000 \text{ mol} - (3)(0.387) = 1.839 \text{ mol H}_2$$

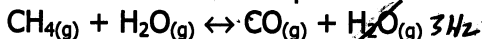
$$[\text{H}_2\text{O}] = .0387 \text{ M} \quad [\text{CH}_4] = .0387 \text{ M}$$

$$[\text{CO}] = .0613 \text{ M} \quad [\text{H}_2] = .1839 \text{ M}$$

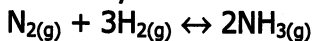
2. a. Write the equilibrium constant expression K<sub>c</sub> for catalytic methanation.



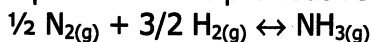
b. Write the equilibrium constant expression K<sub>c</sub> for the reverse of the previous reaction



c. Write the equilibrium constant expression K<sub>c</sub> for the synthesis of ammonia.



d. Write the equilibrium expression K<sub>c</sub> when the equation for the previous reaction is written



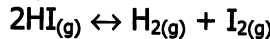
$$a. K_c = \frac{[\text{CH}_4][\text{H}_2\text{O}]}{[\text{CO}][\text{H}_2]^3}$$

$$b. K_c = \frac{[\text{CO}][\text{H}_2]^3}{[\text{CH}_4][\text{H}_2\text{O}]}$$

$$c. K_c = \frac{[\text{NH}_3]^2}{[\text{N}_2][\text{H}_2]^3}$$

$$d. K_c = \frac{[\text{NH}_3]}{[\text{N}_2]^{1/2}[\text{H}_2]^{3/2}}$$

3. Hydrogen iodide, HI, decomposes at moderate temperatures according to the equation



The amount of I<sub>2</sub> in the reaction mixture can be determined from the intensity of the violet color of I<sub>2</sub>; the more intense the color, the more I<sub>2</sub> in the reaction vessel. When 4.00 mol HI was placed in a 5.00L vessel at 458°C, the equilibrium mixture was found to contain 0.442 mol I<sub>2</sub>. What is the value of K<sub>c</sub> for the decomposition of HI at this temperature?

$$0.442 \text{ mol I}_2 \quad 0.442 \text{ mol H}_2$$

$$4.00 \text{ mol HI} - 2(0.442) = 3.116 \text{ mol HI}$$

$$K_c = \frac{[\text{I}_2][\text{H}_2]}{[\text{HI}]^2} = \frac{(0.442)(0.442)}{(3.116)^2} = \boxed{.0201}$$

4. Phosphorus pentachloride dissociates on heating:



If K<sub>c</sub> equals 3.28x10<sup>-2</sup> at 191°C, what is K<sub>p</sub> at this temperature?

$$K_p = K_c(RT)^{\Delta n}$$

$$= 3.28 \times 10^{-2} (.0821 \cdot 464.15)^{(2-1)}$$

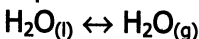
$$= \boxed{1.25}$$

5. a. Quicklime (calcium oxide, CaO) is prepared by heating a source of calcium carbonate, CaCO<sub>3</sub>, such as limestone or seashells.



Write the expression for K<sub>c</sub>.

b. You can write the equilibrium constant expression for a physical equilibrium, such as vaporization, as well as for a chemical equilibrium. Write the expression for K<sub>c</sub> for the vaporization of water.

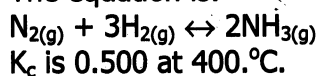


$$a. K_c = [\text{CO}_{2(g)}]$$

$$b. K_c = [\text{H}_2\text{O}_{(g)}]$$

6. A 50.0L reaction vessel contains 1.00mol N<sub>2</sub>, 3.00mol H<sub>2</sub>, and 0.500mol NH<sub>3</sub>. Will more ammonia, NH<sub>3</sub>, be formed or will it dissociate when the mixture goes to equilibrium at 400.°C?

The equation is:

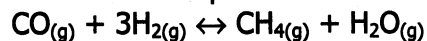


$$Q = \frac{[\text{NH}_3]^2}{[\text{N}_2][\text{H}_2]^3} = 23.1$$

$$= \frac{(0.500/50.0)^2}{(1.00/50.0)(3.00/50.0)^3} = \frac{1.0 \times 10^{-4}}{(0.0200)(2.16 \times 10^{-4})} = 23.1$$

$[Q_c > K_c \text{ NH}_3 \text{ dissociates}]$

7. A gaseous mixture contains 0.30mol CO, 0.10mol H<sub>2</sub>, and 0.020mol H<sub>2</sub>O, plus an unknown amount of CH<sub>4</sub>, in each liter. This mixture is at equilibrium at 1200.K.

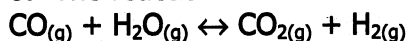


What is the concentration of CH<sub>4</sub> in this mixture? The equilibrium constant K<sub>c</sub> equals 3.92.

$$3.92 = \frac{[\text{CH}_4][0.020/1.00]}{[0.30/1.00][0.10/1.00]^3}$$

$$[\text{CH}_4] = .0588 = \boxed{.059 \text{ M}}$$

8. The reaction



is used to increase the ratio of hydrogen in synthesis gas (mixtures of CO and H<sub>2</sub>). Suppose you start with 1.00mol each of carbon monoxide and water in a 50.0L vessel. How many moles of each substance are in the equilibrium mixture at 1000.°C? The equilibrium constant K<sub>c</sub> at this temperature is 0.58.

$$K_c = \frac{[\text{CO}_2][\text{H}_2]}{[\text{CO}][\text{H}_2\text{O}]}$$

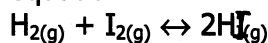
$$0.58 = \frac{[1.00/50.0 - x][1.00/50.0 - x]}{[x][x]}$$

$$0.58 = \frac{[1.00/50.0 - x]^2}{x^2}$$

$$x = .01135 \text{ M } (50.0\text{L}) = .56765 \text{ mol}$$

$[\text{CO}_2 = .432 \text{ mol } \text{H}_2 = .432 \text{ mol } \text{CO} = .568 \text{ mol } \text{H}_2\text{O} = .568 \text{ mol}]$

9. Hydrogen and iodine react according to the equation



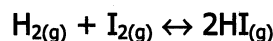
Suppose 1.00mol H<sub>2</sub> and 2.00mol I<sub>2</sub> are placed in a 1.00L vessel. How many moles of substances are in the gaseous mixture when it comes to equilibrium at 458° C? The equilibrium constant K<sub>c</sub> at this temperature is 49.7.

$$K_c = \frac{[\text{HI}]^2}{[\text{H}_2][\text{I}_2]} = \frac{[+2x]^2}{[1.00-x][2.00-x]} = 49.7$$

$$x = .934 \text{ M} = .934 \text{ mol}$$

$$[\text{HI} = 1.87 \text{ mol } \text{H}_2 = .066 \text{ mol } \text{I}_2 = 1.07]$$

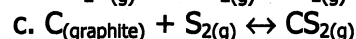
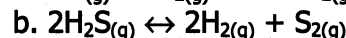
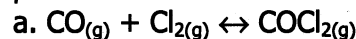
10. Predict the direction of reaction when H<sub>2</sub> is removed from a mixture (lowering its concentration) in which the following equilibrium has been established:



$$K_c = \frac{[\text{HI}]^2}{[\text{H}_2][\text{I}_2]}$$

If you remove H<sub>2</sub> the reaction will be driven towards reactants, "filling in the void"

11. Look at each of the following equations and decide whether an increase of pressure obtained by decreasing the volume will increase, decrease, or have no effect on the amounts of products.



a. Drives towards products (reduces the moles of gas)

b. Drives towards reactants. (reduces moles of gas)

c. No Change. Equivalent moles of gas.

12. Carbon monoxide is formed when carbon dioxide reactions with solid carbon (graphite).



Is a high or low temperature more favorable to the formation of carbon monoxide?

Since the reaction is endothermic raising the temperature will drive the reaction to absorb heat energy (i.e. towards CO product)