AP Chemistry Equilibrium Worksheet

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Name: Key

Date: _____ Period: _____

1. Carbon monoxide and hydrogen react according to the following equation:
$CO_{(g)} + 3H_{2(g)} \leftrightarrow CH_{4(g)} + H_2O_{(g)}$
When 1.000mol CO and 3.000mol H_2 are placed in a 10.00L vessel at 927°C (1200.K) and allowed to come to equilibrium, the mixture is found to contain 0.387mol H_2O. What is the molar composition of the equilibrium mixture? That is, how many moles of each substance are present?

0.387 mol H_2O 0.387 mol CH_4

mol CO = 1.000 − 0.387 = .613 mol CO

mol H_2 = 3.000 mol − (3)(0.387) = 1.839 mol H_2

$[H_2O]$ = .0387M $[CH_4]$ = .0387M

[CO] = .0613M $[H_2]$ = .1839M

2. a. Write the equilibrium constant expression K_c for catalytic methanation.
$CO_{(g)} + 3H_{2(g)} \leftrightarrow CH_{4(g)} + H_2O_{(g)}$
b. Write the equilibrium constant expression K_c for the reverse of the previous reaction
$CH_{4(g)} + H_2O_{(g)} \leftrightarrow CO_{(g)} + \cancel{H_2O_{(g)}}\ 3H_2$
c. Write the equilibrium constant expression K_c for the synthesis of ammonia.
$N_{2(g)} + 3H_{2(g)} \leftrightarrow 2NH_{3(g)}$
d. Write the equilibrium expression K_c when the equation for the previous reaction is written
$\frac{1}{2}\ N_{2(g)} + 3/2\ H_{2(g)} \leftrightarrow NH_{3(g)}$

a. $K_c = \dfrac{[CH_4][H_2O]}{[CO][H_2]^3}$

b. $K_c = \dfrac{[CO][H_2]^3}{[CH_4][H_2O]}$

c. $K_c = \dfrac{[NH_3]^2}{[N_2][H_2]^3}$

d. $K_c = \dfrac{[NH_3]}{[N_2]^{1/2}[H_2]^{3/2}}$

3. Hydrogen iodide, HI, decomposes at moderate temperatures according to the equation
$2HI_{(g)} \leftrightarrow H_{2(g)} + I_{2(g)}$
The amount of I_2 in the reaction mixture can be determined from the intensity of the violet color of I_2; the more intense the color, the more I_2 in the reaction vessel. When 4.00mol HI was placed in a 5.00L vessel at 458°C, the equilibrium mixture was found to contain 0.442mol I_2. What is the value of K_c for the decomposition of HI at this temperature?

0.442 mol I_2 0.442 mol H_2

4.00 mol HI − 2(0.442) = 3.116 mol HI

$K_c = \dfrac{[I_2][H_2]}{[HI]^2} = \dfrac{(.442)(.442)}{(3.116)^2} = \boxed{.0201}$

4. Phosphorus pentachloride dissociates on heating:
$PCl_{5(g)} \leftrightarrow PCl_{3(g)} + Cl_{2(g)}$
If K_c equals 3.28×10^{-2} at 191°C, what is K_p 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, $CaCO_3$, such as limestone or seashells.
$CaCO_{3(s)} \leftrightarrow CaO_{(s)} + CO_{2(g)}$
Write the expression for K_c.
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_c for the vaporization of water.
$H_2O_{(l)} \leftrightarrow H_2O_{(g)}$

a. $K_c = [CO_{2(g)}]$

b. $K_c = [H_2O_{(g)}]$

6. A 50.0L reaction vessel contains 1.00mol N_2, 3.00mol H_2, and 0.500mol NH_3. Will more ammonia, NH_3, be formed or will it dissociate when the mixture goes to equilibrium at 400.°C? The equation is:
$N_{2(g)} + 3H_{2(g)} \leftrightarrow 2NH_{3(g)}$
K_c is 0.500 at 400.°C.

$Q = \frac{[NH_3]^2}{[N_2][H_2]^3} = 23.1$

$= \frac{(0.500/50.0)^2}{(\frac{1.00}{50.0})(\frac{3.00}{50.0})^3} = \frac{1.0\times10^{-4}}{(.0200)(2.16\times10^{-4})} = 23.1$

$[Q_c > K_c$ NH_3 dissociates$]$

7. A gaseous mixture contains 0.30mol CO, 0.10mol H_2, and 0.020mol H_2O, plus an unknown amount of CH_4, in each liter. This mixture is at equilibrium at 1200.K.
$CO_{(g)} + 3H_{2(g)} \leftrightarrow CH_{4(g)} + H_2O_{(g)}$
What is the concentration of CH_4 in this mixture? The equilibrium constant K_c equals 3.92.

$3.92 = \frac{[CH_4][0.020/1.00]}{[0.30/1.00][0.10/1.00]^3}$

$[CH_4] = .0588 = \boxed{.059\ M}$

8. The reaction
$CO_{(g)} + H_2O_{(g)} \leftrightarrow CO_{2(g)} + H_{2(g)}$
is used to increase the ratio of hydrogen in synthesis gas (mixtures of CO and H_2). 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_c at this temperature is 0.58.

$K_c = \frac{[CO_2][H_2]}{[CO][H_2O]}$

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

$0.58 = [1.00/50.0 - x]^2 / x^2$

$x = .01135M\ (50.0L) = .5676\ mol$

$[CO_2 = .432\ mol\ H_2 = .432\ mol\ CO = .568\ mol\ H_2O = .568\ mol]$

9. Hydrogen and iodine react according to the equation
$H_{2(g)} + I_{2(g)} \leftrightarrow 2HI_{(g)}$
Suppose 1.00mol H_2 and 2.00mol I_2 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_c at this temperature is 49.7.

$K_c = \frac{[HI]^2}{[H_2][I_2]} \quad \frac{[+2x]^2}{[1.0M-x][2.0M-x]} = 49.7$

$x = .934M = .934\ mol$

$[HI = 1.87\ mol\ \ H_2 = .066\ mol\ I_2 = 1.07]$

10. Predict the direction of reaction when H_2 is removed from a mixture (lowering its concentration) in which the following equilibrium has been established:
$H_{2(g)} + I_{2(g)} \leftrightarrow 2HI_{(g)}$

$K_c = \frac{[HI]^2}{[H_2][I_2]}$

If you remove H_2 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. $CO_{(g)} + Cl_{2(g)} \leftrightarrow COCl_{2(g)}$
b. $2H_2S_{(g)} \leftrightarrow 2H_{2(g)} + S_{2(g)}$
c. $C_{(graphite)} + S_{2(g)} \leftrightarrow CS_{2(g)}$

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).
$CO_{2(g)} + C_{(graphite)} \leftrightarrow 2CO_{(g)}$; $\Delta H° = +172.5kJ$
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 (ie. towards CO product)