Equilibrium Take-home Quiz (**Due Nov 9th by 8:00 AM**)

1. In your own words, what is meant by "dynamic equilibrium" and how does it relate to chemical reactions?
the state where the concentration of reactants and products has stopped changing
2. Determine which of the following reactions have Kp = Kc. Clearly explain your choice.

$$2\ NO\ (g) + O_2\ (g) \rightleftharpoons 2\ NO_2\ (g)$$
$$O_2\ (g) + N_2\ (g) \rightleftharpoons 2\ NO\ (g)$$

$\Delta n_{gas} = 0$ so $K_p = K_c(RT)^0 = K_c$

3. Calculate K_c for the following reactions given the equilibrium concentrations listed.

$$2\ NOCl\ (g) \rightleftharpoons 2\ NO\ (g) + Cl_2\ (g)$$

[NOCl] = 9.64 mM [Cl_2] = 4.83 mM [NO] = 2.88 mM

4. Using what you learned in Problem 3, determine Kc for the following reaction:

$$NOCl\ (g) \rightleftharpoons NO\ (g) + \tfrac{1}{2}\ Cl_2\ (g)$$

5. Calculate K_P for the reaction in problem 3 if the temperature is 250 °C.

6. Determine the vapor pressure of water (in atm.) at 75 °C is Kp = 38.5630 kPa

7. Consider the following reaction. 1 atm of each reactant is mixed together in a 1 L reaction vessel at 500 °C. At equilibrium the final pressure is found to be 1.924 atm. Determine Kp.

$$N_2\ (g) + 3\ H_2\ (g) \rightleftharpoons 2\ NH_3\ (g)$$

8. Determine the total pressure at equilibrium if 0.20 atm H_2 and 3.0 atm CH_4 (g) are mixed in the presence of 4 grams of carbon at 900 °C.

$$C\ (s) + 2\ H_2\ (g) \rightleftharpoons CH_4\ (g) \qquad Kp = 0.4725\ atm^{-1}\ (\text{at } 900\ °C)$$

9. Calculate the concentration of H_3O^+ that will form if 0.5 M H_2CO_3 (aq) reacts with liquid water to form H_3O^+ and HCO_3^{-1}. Kc = $4.3 \times 10^{-7}\ M^{-1}$ at 25 °C

10. If 25.45 atm of N_2, 10.42 atm. of H_2, and 23.55 atm of NH_3 are present in a reaction vessel, determine if ammonia will decompose or be synthesized.

$$2\ NH_3\ (g) \rightleftharpoons N_2\ (g) + 3\ H_2\ (g) \qquad Kp = 83.4\ atm$$

3. $[NOCl] = 9.64\ mM \left| \frac{10^{-3}\ M}{1\ mM} \right. = 0.00964\ M$ $\quad [Cl_2] = 0.00483\ M$ $\quad [NO] = 0.00258\ M$

$$K_c = \frac{[NO]^2[Cl_2]}{[NOCl]^2} = \frac{(0.00258\ M)^2(0.00483\ M)}{(0.00964\ M)^2} = 4.311 \times 10^{-4}\ M$$

4. $NOCl(g) \rightleftharpoons NO + \frac{1}{2}Cl_2$

This is $\frac{1}{2}$ the equilibrium in problem 3

$K = (4.311 \times 10^{-4}\ M)^{1/2} = 0.0208\ M^{1/2}$

5. $T = 250 + 273.15 = 523.15\ K$ $\quad \Delta n_{gas} = 1$

$K_p = 4.311 \times 10^{-4} \left[(0.08206)(523.15)\right]^1 = 0.0195\ atm$

6. $K_P = P_{H_2O} = 38.5630\ kPa \left| \frac{1\ atm}{101.325\ kPa} \right. = 0.381\ atm$

7. $N_2 + 3H_2 \rightleftharpoons 2NH_3$

	N_2	$3H_2$	$2NH_3$
I	1.00	1.00	0
C	$-x$	$-3x$	$+2x$
E	$1.0-x$	$1-3x$	$2x$

$P_{tot} = 1.924 = 1-x+1-3x+2x$

$1.924 = 2-2x$

$x = 0.038\ atm$

$P_{N_2} = 1-0.038 = 0.962\ atm$

$P_{H_2} = 1-3(0.038) = 0.886\ atm$

$P_{NH_3} = 2(0.038) = 0.076\ atm$

$$K_P = \frac{(0.962)(0.886)^3}{(0.076)^2} = 8.67 \times 10^{-3}\ atm^2$$

8. $C(s) + 2H_2(g) \rightleftharpoons CH_4(g)$

I	0.2 atm	3.0 atm
C	$-2x$	$+x$
E	$0.2-2x$	$3+x$

$$K_p = 0.4725 = \frac{3+x}{(0.2-2x)^2} = \frac{3+x}{0.04-0.8x+4x^2}$$

$$3+x = 0.0189 - 0.378x + 1.89x^2$$

$$0 = 1.89x^2 - 1.378x - 2.9811$$

$$\frac{1.378 \pm \sqrt{(1.378)^2 - 4(1.89)(-2.9811)}}{2(1.89)}$$

$x = -0.9432$

$x = 1.6723$ ← not possible

$(0.2-2(x)) =$ negative

$P_{H_2} = 0.2 - 2(-0.9432) = 2.0864$ atm

$P_{CH_4} = 3 + -0.9432 = 2.0568$ atm

$P_{tot} = 2.0864 + 2.0568 =$ 4.1432 atm

9. $H_2CO_3 + H_2O(\ell) \rightleftharpoons HCO_3^-(aq) + H_3O^+(aq)$

I	0.5 M	0	0
C	$-x$	$+x$	$+x$
E	$0.5-x$	x	x

$$K_c = 4.3\times10^{-7} = \frac{x^2}{\underbrace{0.5-x}_{0.5}}$$

use shortcut

$$4.3\times10^{-7} = \frac{x^2}{0.5}$$

$$x^2 = 2.15\times10^{-4}$$

$$x = 4.64\times10^{-4}\ M$$

$(H_3O^+) = 4.64\times10^{-4}$ M

10. $Q = \frac{(24.45)(10.42)^3}{(23.55)^2} = 49.88$

K > Q

Products form