Equilibrium Worksheet

1. Write the Q expression for the following reactions:

   a) $2H_2(g) + O_2(g) \leftrightarrows 2\ H_2O(g)$

   b) $NH_3(aq) + H_2O(l) \leftrightarrows NH_4^+(aq) + OH^-(aq)$

2. For the reaction $N_2O_4(g) \leftrightarrows 2\ NO_2(g)$ $\Delta H = -56.9$ kJ/mol.
   What happens to Q and K_c for each of the following? Which way will the reaction shift?

   a) remove N_2O_4

   b) raise the temperature

3. For the following reactions, what happens if the volume of the container is decreased.
   Hint: the size of the container only affects the pressure and concentration of a gas.

   a) $A(aq) + B(s) \leftrightarrows C(\ell) + D(g)$

   b) $E(g) \leftrightarrows F(g)$

   c) $2G(g) \leftrightarrows H(g)$

4. $PCl_5(g) \leftrightarrows PCl_3(g) + Cl_2(g)$
   Initially, 0.40 moles of PCl_5 are put in a 10.0 L container. At equilibrium, 0.25 moles of Cl_2 are present.

   What is the value of K_c? Hint: you can fill in the whole table without any x's.

5. $H_2(g) + I_2(g) \rightarrow 2HI(g)$
   The equilibrium concentrations are $[H_2] = 0.46$ M, $[I_2]=0.39$ M, and $[HI] = 3$ M. Calculate K_c.

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6. $A_{(g)} + B_{(g)} \leftrightarrow 2C_{(g)}$. $K_p = 4$
   All species are 1 atm initially. Calculate the equilibrium pressures.

7. Consider the reaction: $CO_{2(g)} + H_{2(g)} \leftrightarrow CO_{(g)} + H_2O_{(g)}$ $K_c = 6$.
   Initially, 1 M CO_2 and 4 M H_2 are present. What are the equilibrium concentrations of all species?

8. $N_2 + 3H_2 \leftrightarrow 2NH_3$ $K_p = 0.5$
   The initial pressures are 1, 2, and 3 atm respectively. Set up the K_p expression but do not solve.
   Hint: make sure to calculate Q first to determine which way the reaction needs to shift.

9. $A(g) + B(g) \leftrightarrow C(g)$ At 25ºC, $K_c = 555$ and $\Delta H^0 = 94$ kJ/mol

   a. Calculate ΔG^0

   b. Calculate K_c at 12ºC

   c. Calculate K_p at 12ºC

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Answers

1. a. $\frac{[H_2O]^2}{[O_2][H_2]^2}$ b. $\frac{[NH_4^+][OH^-]}{[NH_3]}$

2. a. Q increases, K remains the same, so since Q > K the reaction shifts left
   b. Q remains the same, K decreases, so since Q > K the reaction shifts left

3. Decreased volume means increased pressure and concentration.
   a. Left because only [D] increases.
   b. No change. Both [E] and [F] change the same amount and since Q = [F]/[E], Q remains the same.
   c. Right. $Q = \frac{[H]}{[G]^2}$ The denominator increases more than the numerator so Q < K

   Shortcut:
   If V is decreased, the reaction shifts to the side with less moles of gas (takes up less space).
   If V is increased, the reaction shifts to the side with more moles of gas (takes up more space).

4. K = 0.042 (if you got 0.42 it's because you used moles instead of molarity)

5. K = 50.2

6. x= 0.25 so [A] = 0.75 M, [B] = 0.75 M, [C] = 1.5 M

7. The concentrations are 0.05 M, 3.05 M, 0.95 M, and 0.95 M respectively.

8. $\frac{(3-2x)^2}{(1+x)(2+3x)^3} = 0.5$

9. a. 15.6 kJ b. 98.3 c. 4.2