• AP Chemistry

Name _____
Period ___ Date ___/___/___

13 • Chemical Equilibria

PROBLEM SET #1

For the following three reactions,
a) write the K_{eq} expression in terms of concentration, K_c.
b) given the equilibrium concentrations, state whether each equilibrium is product-favored, reactant-favored, or fairly even ([products] ≈ [reactants]).
c) calculate the value of K_c.

1. $N_2(g) + 3\ H_2(g) \leftrightarrows 2\ NH_3(g)$

At equilibrium: R $[N_2] = 1.50$ M, $[H_2] = 2.00$ M, $[NH_3] = 0.01$ M — larger amount

a) $K_c = \frac{[NH_3]^2}{[N_2][H_2]^3}$

b) $K < 1$ reactants are favored

c) $K_c = \frac{[.01]^2}{[1.50][2.00]^3} = 8.33 \times 10^{-6}$

2. $HF(aq) \leftrightarrows H^+(aq) + F^-(aq)$

At equilibrium: R $[HF] = 0.55$ M — larger amount, $[H^+] = 0.001$ M, $[F^-] = 0.001$ M

a) $K_c = \frac{[F^-][H^+]}{[HF]}$

b) $K < 1$ reactants are favored

c) $K_c = \frac{[.001][.001]}{[.55]} = 1.8 \times 10^{-6}$

3. $Fe^{3+}(aq) + SCN^-(aq) \leftrightarrows FeSCN^{2+}(aq)$

At equilibrium: R $[Fe^{3+}] = 0.55$ M, $[SCN^-] = 0.001$ M, $[FeSCN^{2+}] = 0.001$ M

a) $K_c = \frac{[FeSCN^{+2}]}{[Fe^{+3}][SCN^-]}$

b) $K > 1$ products are favored

c) $K_c = \frac{.001}{[.55][.001]} = 1.8$

Summarize:
Fill in the blanks with product-favored, reactant-favored, and approximately equal

K_c	state of equilibrium
$K_c >> 1$	product favored
$K_c << 1$	reactant favored
$K_c \approx 1$	equal

4. Knowing that pure water has a density of 1g/1mL calculate the mass of 1.00 Liter of water.

$D = 1\ g/mL$ $\quad 1 = \frac{x\ g}{1000\ mL} = 1000\ g$

Calculate the number of moles in 1.00 L of H_2O.

$1000\ g\ H_2O \left| \frac{1\ mol}{18.0169\ g\ H_2O} \right. = 55.5\ mol\ H_2O$

What is the concentration (M) of water in water?

$M = \frac{55.5\ mol}{1\ L} = 55.5\ M$

At this temperature, can you get more moles of water into this Liter of water? No

The $[H_2O]$ ___is___ (is / is not) constant.

Important Note:
Since the concentrations of solids and liquids are constant, they are incorporated into the equilibrium constant, K_{eq}. That means, just leave them out of the K_c or K_p expression. Only include (g) and (aq)!

5. Write equilibrium expressions for each of the following reactions:

a) $CaCO_3(s) \rightleftharpoons CaO(s) + CO_2(g)$

$K_c = K = K_{eq} = [CO_2]$

b) $Ni(s) + 4CO(g) \rightleftharpoons Ni(CO)_4(g)$

$K_c = \frac{[Ni(CO)_4]}{[CO]^4}$

c) $5CO(g) + I_2O_5(s) \rightleftharpoons I_2(g) + 5CO_2(g)$

$K_c = \frac{[I_2][CO_2]^5}{[CO]^5}$

d) $Ca(HCO_3)_2(aq) \rightleftharpoons CaCO_3(s) + H_2O(l) + CO_2(g)$

$K_c = \frac{[CO_2]}{[Ca(HCO_3)_2]}$

e) $AgCl(s) \rightleftharpoons Ag^+(aq) + Cl^-(aq)$

$K_c = [Ag^+][Cl^-]$

6. Write the equilibrium expression in terms of partial pressures (K_p) for each of the following reactions.
Rate the reactions in order of their increasing tendency to proceed toward completion:

b c d a *larger K more to completion

(a) $4NH3(g) + 3O2(g) \rightleftharpoons 2N2(g) + 6H2O(g)$
$K_p = 1 \times 10^{228}$ atm

$$K_p = \frac{(P_{N_2}{}^2)(P_{H_2O})^6}{(P_{NH_3})^4 (P_{O_2})^3}$$

(b) $N2(g) + O2(g) \rightleftharpoons 2NO(g)$
$K_p = 5 \times 10^{-31}$

$$K_p = \frac{P_{NO}{}^2}{P_{N_2} \cdot P_{O_2}}$$

(c) $2HF(g) \rightleftharpoons H2(g) + F2(g)$
$K_p = 1 \times 10^{-13}$

$$K_p = \frac{P_{H_2} \cdot P_{F_2}}{P_{HF}{}^2}$$

(d) $2NOCl(g) \rightleftharpoons 2NO(g) + Cl2(g)$
$K_p = 4.7 \times 10^{-4}$ atm

$$K_p = \frac{P_{NO}{}^2 \cdot P_{Cl_2}}{P_{NOCl}{}^2}$$

A Question That You Should Be Able To Answer:
Why don't the K_p's in (b) and (c) have units?

cancel out

7. (a) Write the K_c expression for
$2\ SO_2(g) + O_2(g) \leftrightarrows 2\ SO_3(g)$

$$K_c = \frac{[SO_3]^2}{[SO_2]^2[O_2]}$$

Calculate the value of K_c:
At equilibrium: $[SO_2] = 1.50$ M
$[O_2] = 1.25$ M
$[SO_3] = 3.50$ M

$$K_c = \frac{(3.50)^2}{(1.50)^2(1.25)} = 4.36$$

(b) If we **reverse** the equation, it is:
$2\ SO_3(g) \leftrightarrows 2\ SO_2(g) + O_2(g)$
Write the K_c expression for this equation and calculate the new value of K_c:

$$K_c = \frac{[SO_2]^2[O_2]}{[SO_3]^2}$$

$$K_c = \frac{1}{4.36} = .229$$

How does the expression and the value of K_c in 7(b) compare with those in 7(a)?
a → greater than 1 (favors products)
b → less than 1 (favors reactants)

(c) If we now **multiply all of the coefficients by ½:**
$SO_3(g) \leftrightarrows SO_2(g) + \frac{1}{2}\ O_2(g)$
Write the K_c expression for this equation and calculate the new value of K_c:

$$K_c = \frac{[SO_2][O_2]^{1/2}}{(SO_3)} = \frac{(1.50)(1.25^{1/2})}{3.50}$$

$K_c = .479$

How do they compare with 7(b)?

about the square root of K

(d) What would happen to the K_c expression and its value if we **doubled** the coefficients?

K^2

Summarize:

Equation	K_c expression & Value
doubled	K^2
reversed	inverse
halved	$K^{0.5}$

8. Consider an equilibrium that occurs in two steps:
$H_2S(aq) \leftrightarrows H^+(aq) + HS^-(aq)$
$HS^-(aq) \leftrightarrows H^+(aq) + S^{2-}(aq)$
$H_2S \rightleftharpoons 2H^+ + S^{-2}$

(a) Write the overall reaction.
(b) How do the K_c's for the two steps (K_{c1} & K_{c2}) relate to the K_c of the overall reaction (K_c)?

multiplied together

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