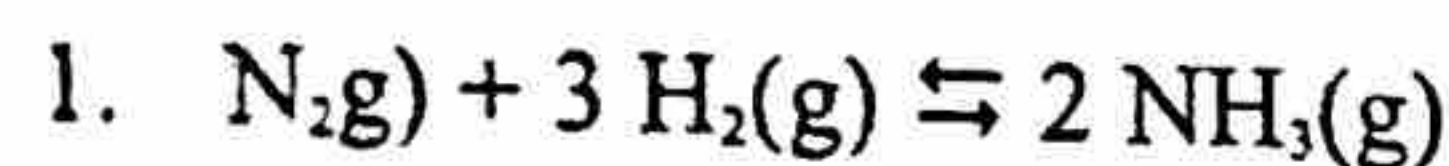


13 • Chemical Equilibria

PROBLEM SET #1

For the following three reactions,

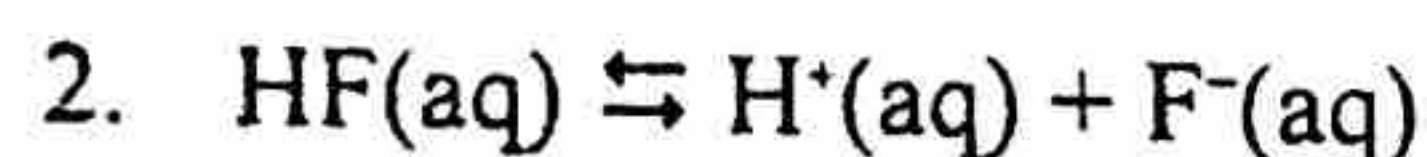
- write the K_{eq} expression in terms of concentration, K_c .
- given the equilibrium concentrations, state whether each equilibrium is product-favored, reactant-favored, or fairly even ($[products] \approx [reactants]$).
- calculate the value of K_c .



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

a) $K_c = \frac{[NH_3]^2}{[N_2][H_2]^3}$ b) $K < 1$ reactants are favored

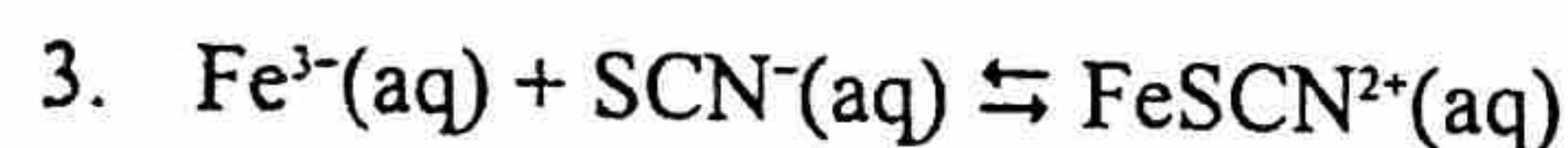
c) $K_c = \frac{[0.01]^2}{[1.50][2.00]^3} = 8.33 \times 10^{-6}$



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) $K_c = \frac{[0.001][0.001]}{[0.55]} = 1.8 \times 10^{-6}$



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) $K_c = \frac{0.001}{[0.55][0.001]} = 1.8$

Summarize:

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

K_c	state of equilibrium
$K_c \gg 1$	product favored
$K_c \ll 1$	reactant favored
$K_c \approx 1$	equal

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

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

Calculate the number of moles in 1.00 L of H_2O .

$\frac{1000g H_2O}{18.016g H_2O} = 55.5 mol H_2O$

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

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

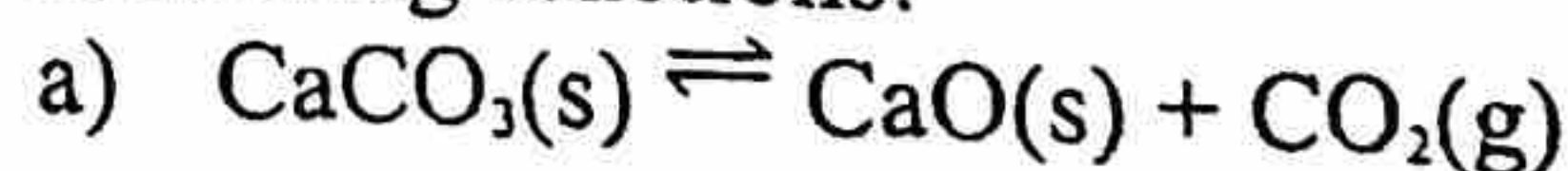
At this temperature, can you get more moles of water into this Liter of water? **No**

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

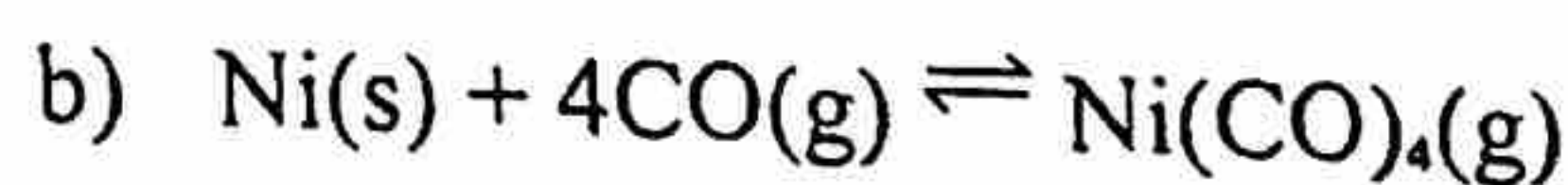
Important Note:

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)!

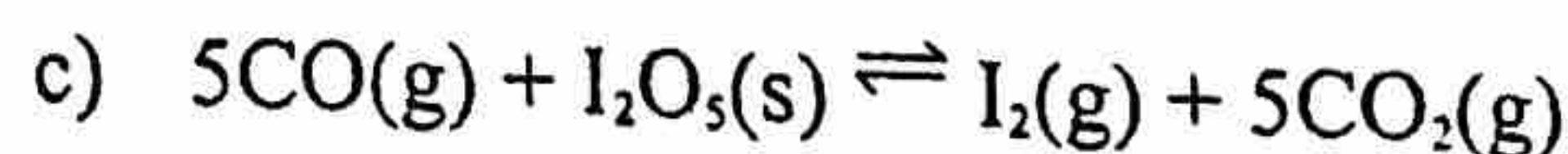
5. Write equilibrium expressions for each of the following reactions:



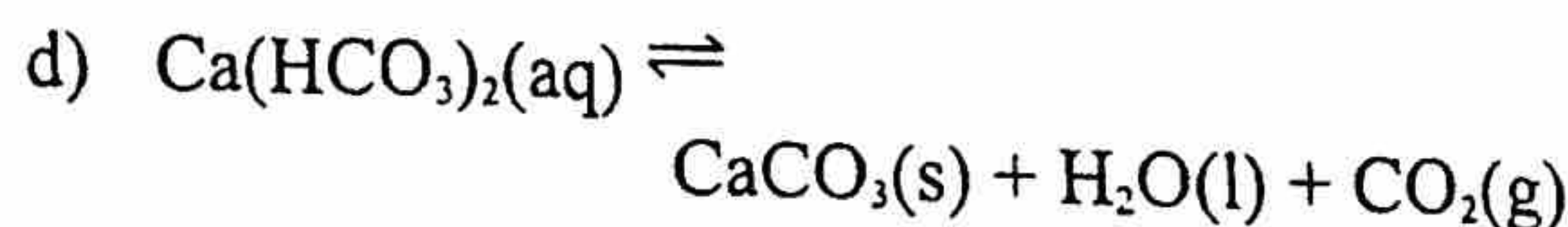
$K_c = K = K_{eq} = [CO_2]$



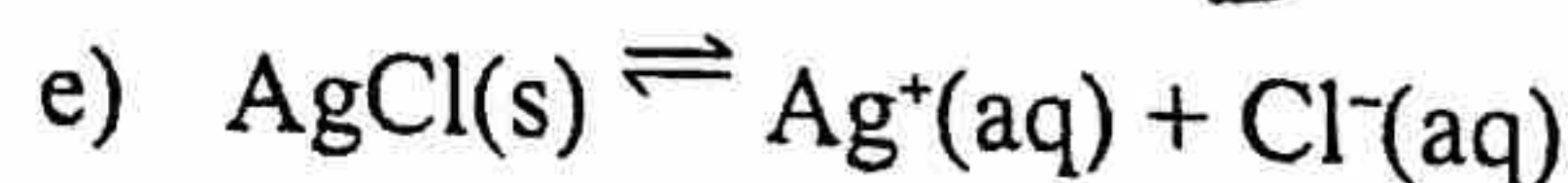
$K_c = \frac{[Ni(CO)_4]}{[CO]^4}$



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



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

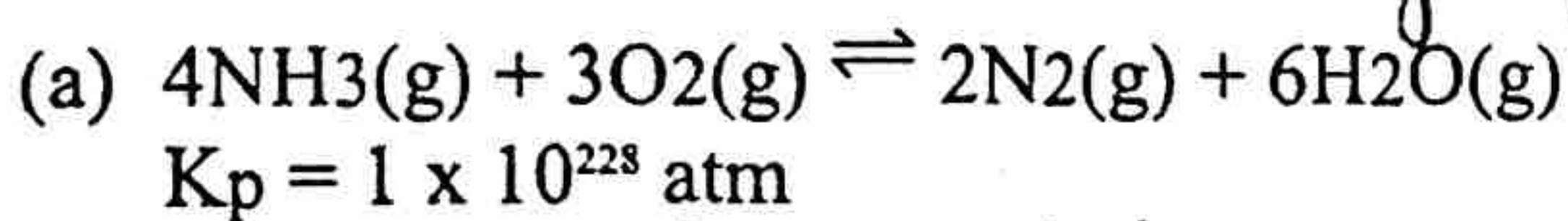


$K_c = [Ag^+][Cl^-]$

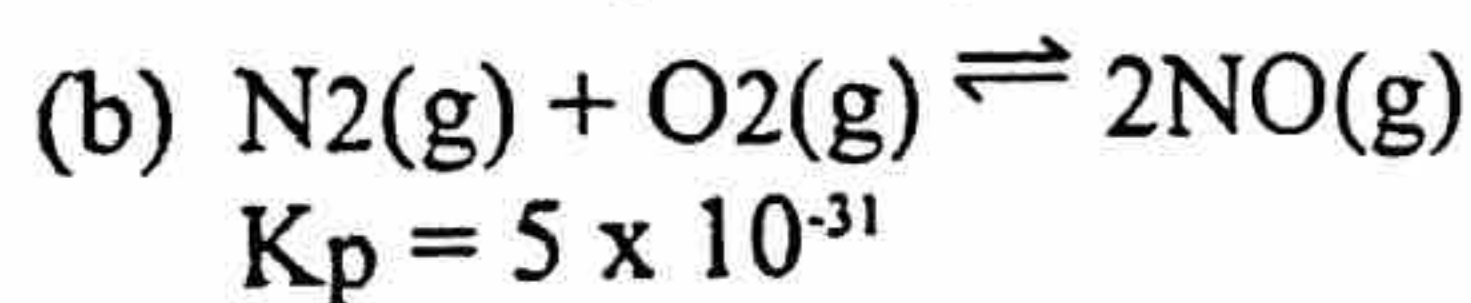
6. Write the equilibrium expression in terms of partial pressures (K_p) for each of the following reactions.

Rate the reactions in order of their increasing tendency to proceed toward completion:

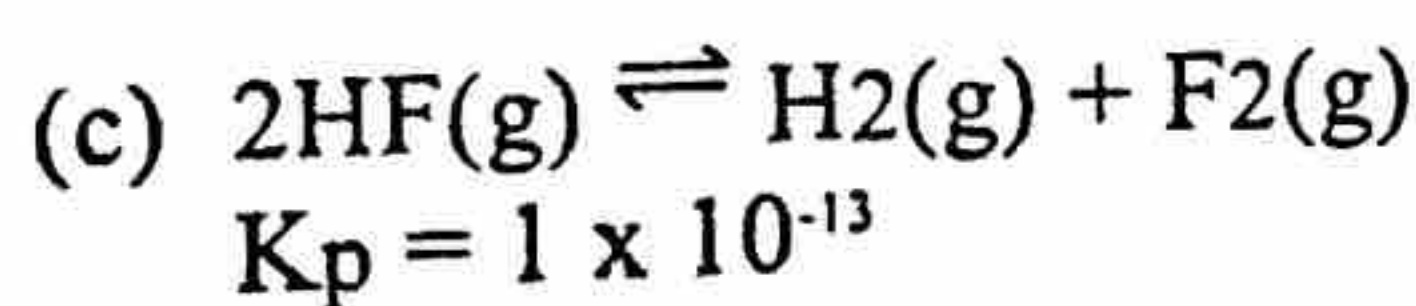
b c d a * larger K more to completion



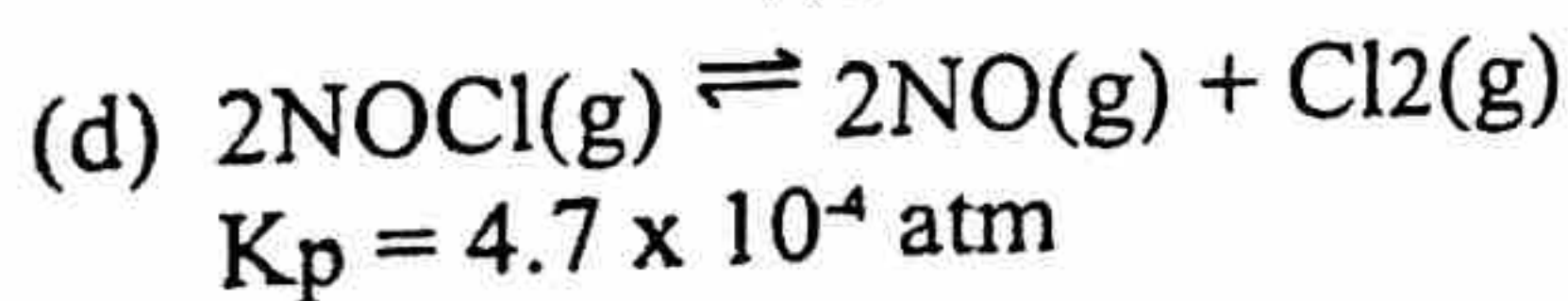
$$K_p = \frac{(P_{\text{N}_2})^2 (P_{\text{H}_2\text{O}})^6}{(P_{\text{NH}_3})^4 (P_{\text{O}_2})^3}$$



$$K_p = \frac{P_{\text{NO}}^2}{P_{\text{N}_2} \cdot P_{\text{O}_2}}$$



$$K_p = \frac{P_{\text{H}_2} \cdot P_{\text{F}_2}}{P_{\text{HF}}^2}$$



$$K_p = \frac{P_{\text{NO}}^2 \cdot P_{\text{Cl}_2}}{P_{\text{NOCl}}^2}$$

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
 $2\text{SO}_2(\text{g}) + \text{O}_2(\text{g}) \rightleftharpoons 2\text{SO}_3(\text{g})$

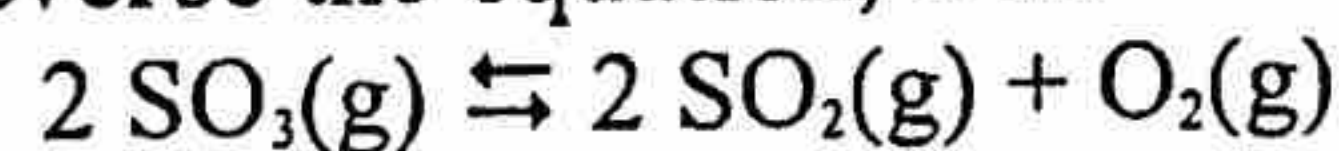
$$K_c = \frac{[\text{SO}_3]^2}{[\text{SO}_2]^2 [\text{O}_2]}$$

Calculate the value of K_c :

At equilibrium: $[\text{SO}_2] = 1.50 \text{ M}$
 $[\text{O}_2] = 1.25 \text{ M}$
 $[\text{SO}_3] = 3.50 \text{ M}$

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

(b) If we reverse the equation, it is:



Write the K_c expression for this equation and calculate the new value of K_c :

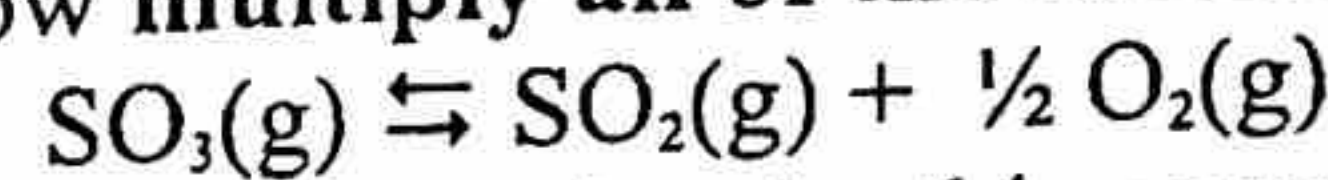
$$K_c = \frac{[\text{SO}_2]^2 [\text{O}_2]}{[\text{SO}_3]^2}$$

$$K_c = \frac{1}{4.36} = 0.229$$

How does the expression and the value of K_c in 7(b) compare with those in 7(a)?

a \rightarrow greater than 1 (favors products)
 b \rightarrow less than 1 (favors reactants)

(c) If we now multiply all of the coefficients by $\frac{1}{2}$:



Write the K_c expression for this equation and calculate the new value of K_c :

$$K_c = \frac{[\text{SO}_2][\text{O}_2]^{1/2}}{[\text{SO}_3]} = \frac{(1.50)(1.25)^{1/2}}{3.50}$$

$$K_c = 0.479$$

How do they compare with 7(b)?

~~same as~~
 $K^{1/2}$

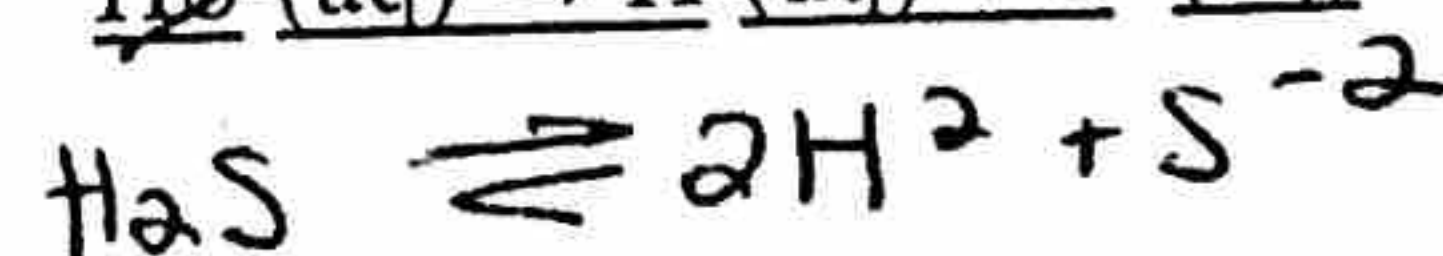
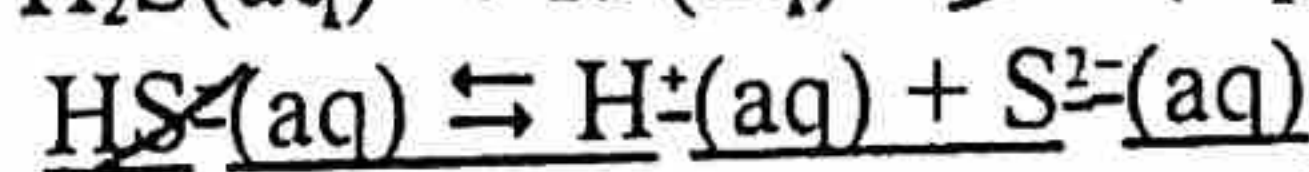
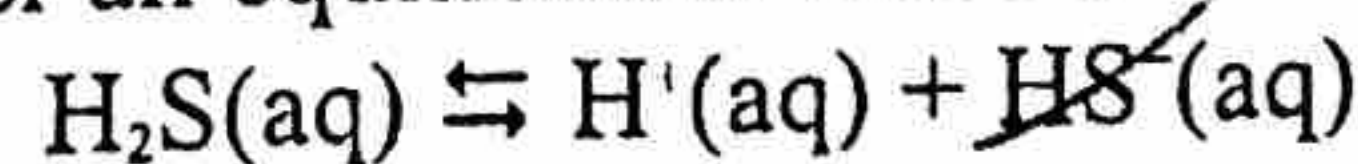
(d) What would happen to the K_c expression and its value if we doubled the coefficients?

K^2

Summarize:

Equation	K_c expression & Value
doubled	K^2
reversed	inverse
halved	$K^{1/2}$

8. Consider an equilibrium that occurs in two steps:



(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