You're on K_p Duty

[67 marks]

(60.5/67) 90% April 23rd 2018

KU 13/18

Making Connections [15 marks]

1. Consider the following system at equilibrium, $3Zn(s) + 2H_3PO_4(aq) \leftrightarrow Zn_3(PO_4)_2(aq) + 3H_2(g)$.

   (a) Write out the equilibrium expression. [2 marks]

2

$$K_c = \frac{[H_2]^3[Zn_3(PO_4)_2]}{[H_3(PO_4)]^2}$$

   (b) Use the concept of entropy to determine where the heat term should be placed. Explain your reasoning. [3 marks]

3

The heat term should be placed on the left side b/c the right side has a gas and gases are more disorder than aqueous solns so since the right side has more disorder the heat term is placed on the opposite side.

   (c) Identify the direction the system will shift for each of the following actions taken on the original system at equilibrium. Show concentration changes where applicable and explain, using Le Chatelier's principle, why the shift takes place. [10 marks]

10

Action	Direction of Shift & Explanation
pressure on the system is increased P↑ V↓	← ✓ ↑P: shifts to side with fewer moles of gas
the temperature of the system is increased	→ ✓ ↑T: shifts away from heat
some hydrogen is removed from the system	→ ✓ ↓H_2: there's a hole in H_2 that needs to be filled so shift right
some zinc is added to the system	— ✓ (s), (ℓ) do not affect EQ position
a catalyst is added to the system	— ✓ catalysts don't eq. position

The value of $Ce(OH)_3$ in solution. [1]

K_{sp} =

Communication [4 marks] (3)

2. The K_p for the equilibrium, $N_2(g) + 3H_2(g) \leftrightarrow 2\,NH_3(g)$, is 4.51×10^{-5} at 450°C. If 105 atm $NH_3(g)$, 55 atm $H_2(g)$ and 5.0 atm $N_2(g)$ is placed in a reaction vessel, is the mixture at equilibrium? If not, in what direction must the reaction proceed to attain equilibrium? Fully explain your reasoning. [4 marks]

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

$K_p = 4.51 \times 10^{-5}$

$$Q = \frac{(pNH_3)^2}{(pH_2)^3(pN_2)}$$

$$Q = \frac{(105)^2}{(55^3)(5.0)}$$

$$Q = \frac{11025}{831875}$$

$Q = 0.013253193$

3

∴ Since Q > K the rxn will shift ← towards the Rs so no, the rxn is not at eq. The direction the rxn must move in to get to eq would be right (→)

huh?!?

Inquiry [30 marks] (29.5) $Q = 1.3 \times 10^{-2}$

3. The following unbalanced reaction, $H_2(g) + Cl_2(g) \leftrightarrow HCl(g)$, has the equilibrium constant, K_c=300 at 400°C. Determine the equilibrium concentrations of all reactants and products if initially 0.440 mol of HCl(g) is injected into a 2.0 L flask at 400°C and allowed to come to equilibrium. Show all equations and charts in your full solution. [10 marks]

$H_2(g) + Cl_2(g) \rightleftharpoons 2HCl(g)$ $K_c = 300$

	H_2	Cl_2	$2HCl$
I	0	0	0.22 M
C	+x	+x	−2x
E	x	x	0.22 − 2x

$= 0.22 - 2(0.011)$

$= 0.198\,M$

∴ the $[H_2]$ would be 0.011 M and same for the $[Cl_2]$ would be 0.011M

The $[HCl]$ would be 0.198 M

80

$$Q_c = \frac{[HCl]^2}{[Cl_2][H_2]}$$

$$\sqrt{300} = \sqrt{\frac{(0.22-2x)^2}{x^2}}$$

$$300 = \frac{(0.22-2x)^2}{(x)(x)}$$

$$\sqrt{300} = \frac{(0.22-2x)}{x}$$

$17x = 0.22 - 2x$

$19x = 0.22$

$x = 0.011386864$

$x = 0.011 \rightarrow 1.1 \times 10^{-2}\,M$

The value of K_{sp} for cerium hydroxide, $Ce(OH)_3$, is 1.5×10^{-20}. What is the molar solubility of $Ce(OH)_3$ in a solution that contains 0.10 M NaOH? Show all equations and charts in your full solution. [10 marks]

$K_{sp} = 1.5 \times 10^{-20}$

$$Ce(OH)_{3(s)} \rightleftharpoons Ce^{3+}_{(aq)} + 3OH^-_{(aq)}$$

I	X	0 / 0.10
C	X	x / 3x
E	X	x / 0.10 + 3x

10

$K_{sp} = [OH^-]^3[Ce^{3+}]$

$1.5 \times 10^{-20} = (0.10 + 3x)^3(x)$

$1.5 \times 10^{-20} = (0.10)^3(x)$

$1.5 \times 10^{-20} = 0.001x$

$1.5 \times 10^{-17} = x$ $\frac{mol}{L}$

∴ the molar solubility of $Ce(OH)_3$ would be $1.5 \times 10^{-17} \frac{mol}{L}$

5. Will a precipitate form when 0.150 L of 3.0×10^{-3} M barium nitrate solution is added to 0.350 L of 5.0×10^{-3} M sodium sulfate solution? [10 marks]

$K_{sp} = 1.1 \times 10^{-10}$

$C = 3.0 \times 10^{-3}$ M, $V = 0.150$ L $\}$ $Ba(NO_3)_2$

$C = 5.0 \times 10^{-3}$ M, $V = 0.350$ L $\}$ $Na(SO_4)_2$

$$Ba(NO_3)_{2(aq)} + Na(SO_4)_{2(aq)} \rightarrow \boxed{Ba(SO_4)_{(s)}} + Na(NO_3)_{(aq)}$$

$$Ba(SO_4)_{(s)} \rightleftharpoons Ba^{2+}_{(aq)} + SO_4^{2-}_{(aq)}$$

$C_1V_1 = C_2V_2$

$(3.0 \times 10^{-3}\text{M})(0.150\text{L}) = C_2(0.500\text{L})$

$0.0009 = C_2$

$9.0 \times 10^{-4}\text{ M} = C_2$

10

$C_1V_1 = C_2V_2$

$(5.0 \times 10^{-3}\text{M})(0.350\text{L}) = C_2(0.500\text{L})$

$0.0035 = C_2$

$3.5 \times 10^{-3}\text{ M} = C_2$

$Q = [Ba^{2+}][SO_4^{2-}]$

$= (9.0 \times 10^{-4}\text{M})(3.5 \times 10^{-3}\text{M})$

$= 0.00000315$

$= 3.2 \times 10^{-6}$ M

∴ Because $Q > K$ the rxn will proceed towards the left (←) and so yes, a precipitate will form.

$$Q = \frac{(pNH_3)^2}{(pH_2)^3 (pN_2)}$$

$Q > K$

$\therefore$ rxn is NOT at equilibrium

$$= \frac{(105\,atm)^2}{(55)^3 (5.0)}$$

$\therefore$ To reach equilibrium the rxn must proceed right.

$= 0.013253193$

$= 1.33 \times 10^{-2}$

3. $K_c = 300$

$H_{2(g)} + Cl_{2(g)} \rightleftarrows 2HCl_{(g)}$

I	$\emptyset$	$\emptyset$	0.22
C	x	x	$-2x$
E	x	x	$0.22-2x$

$$300 = \frac{(0.22-2x)^2}{x^2}$$

$$\sqrt{300} = \frac{0.22-2x}{x}$$

$$(\sqrt{300})(x) = 0.22-2x$$

$$17.32x = 0.22-2x$$

$$19.32x = 0.22$$

$$x = 0.011387164\,M$$

Assignment - 1st

1. ✓ $K_c = 1 \times 10^{-30}$, since Kc is a VERY small # that means the ratio of products over reactants it's very low, and it doesn't favour products.

2. a) ✓ ⟶ c) ✓ —
✓ b) ✓ ⟷ d) ✓ ⟵

9. ✓ $Zn(Cn)_{2(s)} \rightarrow Zn^{+2}_{(aq)} + 2CN^-_{(aq)}$

I	X	Ø	0.20
C	X	x	2x
E	X	x	0.20+2x

$K_{sp} = 8.0 \times 10^{-12}$

$K_{sp} = [CN]^2[Zn]$

$8.0 \times 10^{-12} = (0.20+2x)^2(x)$

$8.0 \times 10^{-12} = 0.04x$

$\boxed{2.0 \times 10^{-10} M = x}$

Assignment

1. Lower temp b/c Kc is larger ∴ Ratio of $\frac{[P]}{[R]}$ is high,

Test

1. ✓ a) $K_c = \frac{[H_2]^3 [Zn_3(PO_4)]}{[H_3PO_4]^2}$

b) Should be on the left side cuz opposite from the most disorder (entropy).

2. ✓
a) ⟵ ✓
b) ⟶ ✓
c) ⟶ ✓
d) — ✓
e) — ✓

4. $K_{sp} = 1.5 \times 10^{-20}$

$\left(\frac{mol}{L}\right)\left(\frac{g}{mol}\right) = g/L$

$Ce(OH)_{3(s)} \rightarrow Ce^{+3}_{(aq)} + 3OH^-_{(aq)}$

I	X	0	0.10
C	X	x	$3x$
E	X	x	$0.10 + 3x$

$1.5 \times 10^{-20} = (x)(0.10 + 3x)^3$

$1.5 \times 10^{-20} = (x)(0.001)$

$1.5 \times 10^{-17} = x \frac{mol}{L}$

5.

$c = 3.0 \times 10^{-3} M$, $V = 0.150 L$ } $Ba(NO_3)_2$

$c = 5.0 \times 10^{-3} M$, $V = 0.350 L$ } $Na_2(SO_4)$

$C_1V_1 = C_2V_2$

$(3.0 \times 10^{-3})(0.150 L) = C_2 (0.500 L)$

$0.0009 M = C_2$

$C_1V_1 = C_2V_2$

$(5.0 \times 10^{-3})(0.350 L) = C_2 (0.500)$

$0.0035 M = C_2$

$Ba(NO_3)_{2(aq)} + Na_2(SO_4)_{(aq)} \rightarrow Ba(SO_4)_{(s)} + Na(NO_3)_{(aq)}$

$Ba(SO_4)_{(s)} \rightleftarrows Ba^{+2}_{(aq)} + SO_4^{2-}_{(aq)}$

$Q = (0.0009)(0.0035)$

$Q = 3.15 \times 10^{-6}$

$K_{sp} = 1.1 \times 10^{-10}$

$Q > K$

rxn goes ← so yes precipitate forms!