You're on K_p Duty

[67 marks]

34/67 53%

KU 10/18

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]

$K_c = \frac{[H_2]^3}{[H_3PO_4]^2}$ (solids left out)

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

$3Zn(s) + 2H_3PO_4(aq) + heat \rightleftharpoons Zn_3(PO_4)_2(aq) + 3H_2(g)$

Place nrg opposite left side of max disorder

left side → 5 moles, right side → 4 moles

(g) is most random, then (aq), then (s)

- only compare moles of certain states

entropy = chaos/disorderedness of a system

Side with more disorder is left side (more moles), so heat term is placed on side opposite to the side with more chaos. Heat term is on right side. heat term → reactant 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]

Action	Direction of Shift & Explanation
pressure on the system is increased ←	Shift ← ✓ Le Chatelier's principal states that a system will do the opposite of what you do to it in terms of [ ], V or P (increasing/decreasing) - If P ↑ will shift to side with more moles ✗
the temperature of the system is increased Shifts to remove added heat →	Shift ← ✗ If T ↑, system shifts to side with more moles
some hydrogen is removed from the system Shifts to replace → lost gas	Shift → ✓ System wants to even out, so it tries to fill the gap H_2 left by being removed, shifting towards products. Concentration of H_2 ↓ from products
some zinc is added to the system addition of solid does not affect system	Shift → ✗ More zinc added, the system tries to even out and moves towards the products. The [ ] of Zn is changed (increased) from reactants
a catalyst is added to the system	✓ ^ catalyst does not affect anything here ← explain allows eq to be reached faster, does not affect eq. position

shifts to side w/ less moles

[R] ↑ [P] ↓

[P] ↓ [P] ↑

[R] ↓ [P] ↑

[R] - [P] -

[R] - [P] -

P ↑ V ↓ → more moles

P ↓ V ↑ → less moles

T ↑ → more moles

T ↓ → less moles

4-

Communication [4 marks]

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]

$K_p = 4.51 \times 10^{-5} = 0.0000451$

$pNH_3 = 105\ atm$

$pH_2 = 55\ atm$

$pN_2 = 5.0\ atm$

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

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

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

~~$Q = 0.7289$~~

~~$Q = 7.5 \times 10^{-1}$~~

$Q = 1.3 \times 10^{-2}$

$Q > K_p$ $\quad Q \neq K_p$

No, Q and Kp do not equal each other, mixture is not at eq.

the product quantity will ↓, shift to reactants, shift ←

P & R ratio must ↓ from 1.3×10^{-2} to 4.5×10^{-5}

Inquiry [30 marks] (15)

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]

$H_2(g) + Cl_2(g) \rightleftharpoons 2HCl(g)$

$K_c = 300$

$[HCl] = \dfrac{n}{V} = \dfrac{0.440\ mol}{2.0\ L} = 0.22\ mol/L$

$H_2(g) + Cl_2(g) \rightleftharpoons 2HCl(g)$

I	0	0	0.22
C	+x	+x	−2x
E	+x	+x	0.22 − 2x

$Q > K_p$

$Q < K_p$

$300 = \dfrac{[HCl]^2}{[Cl_2][H_2]}$

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

$\sqrt{300} = \dfrac{0.22 - 2x}{+x}$

$x = 0.011$, sub in

$-17.320x = 0.22 + 2x$

$-19.32x = 0.22$

$x = -0.01$ ← does this make sense?

$[HCl] = 0.22 + 2(-0.01) = 0.2\ M$

$[Cl_2] = -(-0.01) = 0.01\ M$

$[H_2] = -(-0.01) = 0.01\ M$

↳ eq. [ ]

mol/L

4. 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]

$Ce(OH)_3(s) \rightleftharpoons Ce^{3+}(aq) + 3OH^-(aq)$

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

*side that starts w/ 0 should be +x. The side that starts with 0 should be on right cuz it's being made

	$Ce^{3+}(aq)$	+	$3OH^-(aq)$	$\rightleftharpoons$	$Ce(OH)_3(s)$
I	0		0		
C	+x		+3x		-x
E	x		0.1+3x		?

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

$1.5 \times 10^{-20} = x(0.1+3x)^3$

$x \approx 0.1$

$1.5 \times 10^{-20} = \frac{(x)(0.1)^3}{(1)}$

$x = \frac{(1.5 \times 10^{-20})(1)}{(0.1)^3}$

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

$K_{sp} = 1.5 \times 10^{-17}$

∴ molar solubility is 1.5×10^{-17} mol/L of 0.10M $NaOH_{(aq)}$

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]

$Ba(NO_3)_{2(aq)} + Na_2SO_{4(aq)} \rightarrow BaSO_{4(s)} + NaNO_{3(aq)}$

$BaSO_{4(s)} \rightleftharpoons Ba^{2+}(aq) + SO_4^{2-}(aq)$

$K(BaSO_4) = 1.1 \times 10^{-10}$

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

$Q > K$

yes precipitate will form, [P] ↓, rxn shifts left towards solid

$Ba(NO_3)_2$ $C_1V_1 = C_2V_2$

$(3.0 \times 10^{-3}\,M)(0.150\,L) = C_2(0.5\,L)$

$C_2 = 0.0009\,M = 9.0 \times 10^{-4}\,M$

Na_2SO_4 $C_1V_1 = C_2V_2$

$(5.0 \times 10^{-3}\,M)(0.350\,L) = C_2(0.5\,L)$

$C_2 = 0.0035\,M = 3.5 \times 10^{-3}\,M$

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

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

$Q = (0.0009\,M)(0.0035\,M)$

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