

You're on K<sub>p</sub> Duty  
[67 marks]

34  
67 53%

KU 10/18

Making Connections [15 marks]

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

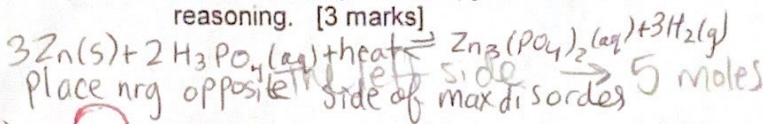
(a) Write out the equilibrium expression. [2 marks]

0

~~$K_c = \frac{[H_2]^3 [Zn_3(PO_4)_2]}{[H_3PO_4]^2}$~~

$K_c = \frac{[H_2]^3 [Zn_3(PO_4)_2]}{[H_3PO_4]^2}$

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



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

(g) is most random, right side → 4 moles then (aq), then (s)

- only compare moles of certain states  
Entropy = chaos/disorder of a system

(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]

P ↑ V ↓ → more moles  
P ↓ V ↑ → less moles  
T ↑ → more moles  
T ↓ → less moles

4

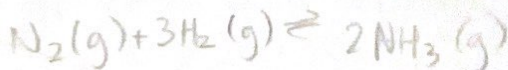
Action	Direction of Shift & Explanation
pressure on the system is increased ←	Shift ← Le Chatelier's principle states that a system will do the opposite of what you do to it in terms of [ ], V or P (increasing/decreasing). If P ↑, will shift to side with more moles ×
the temperature of the system is 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 <sub>2</sub> left by being repaired, shifting towards products. Concentration of H <sub>2</sub> ↓ 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
a catalyst is added to the system —	✓ a catalyst does not affect anything here explain allows eq. to be reached faster, not affect eq. position

Shifts to side w/ less moles  
[P] ↑  
[P] ↓  
[P] ↓  
[P] ↑  
[P] ↓  
[P] ↑  
[P] -  
[P] -  
[P] -  
[P] -

**Communication [4 marks]**

2. The  $K_p$  for the equilibrium,  $N_2(g) + 3H_2(g) \leftrightarrow 2NH_3(g)$ , is  $4.51 \times 10^{-5}$  at  $450^\circ C$ . 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]

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



$P_{NH_3} = 105 \text{ atm}$

$P_{H_2} = 55 \text{ atm}$

$P_{N_2} = 5.0 \text{ atm}$

$Q = \frac{(P_{NH_3})^2}{(P_{H_2})^3 (P_{N_2})}$

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

~~$Q = 0.7289$~~   $Q = 1.3 \times 10^{-2}$   
 ~~$Q = 7.5 \times 10^{-1}$~~

$Q > K_p$      $Q \neq K_p$

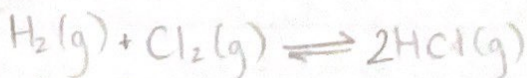
No,  $Q$  and  $K_p$  do not equal each other, mixture is not at eq.

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

$P \cdot R$  ratio must ↓ from  $1.3 \times 10^{-2}$  to  $4.5 \times 10^{-5}$

**Inquiry [30 marks]**

3. The following unbalanced reaction,  $H_2(g) + Cl_2(g) \leftrightarrow HCl(g)$ , has the equilibrium constant,  $K_c = 300$  at  $400^\circ C$ . 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  $400^\circ C$  and allowed to come to equilibrium. Show all equations and charts in your full solution. [10 marks]



$K_c = 300$

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



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

$Q > K_p$

$Q < K_p$

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

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

$300 = \frac{0.22+2x}{x}$

$x = 0.011$ , Sub in

$-17.320x = 0.22 + 2x$

$-19.32x = 0.22$

$x = -0.01$  ← does this make sense?

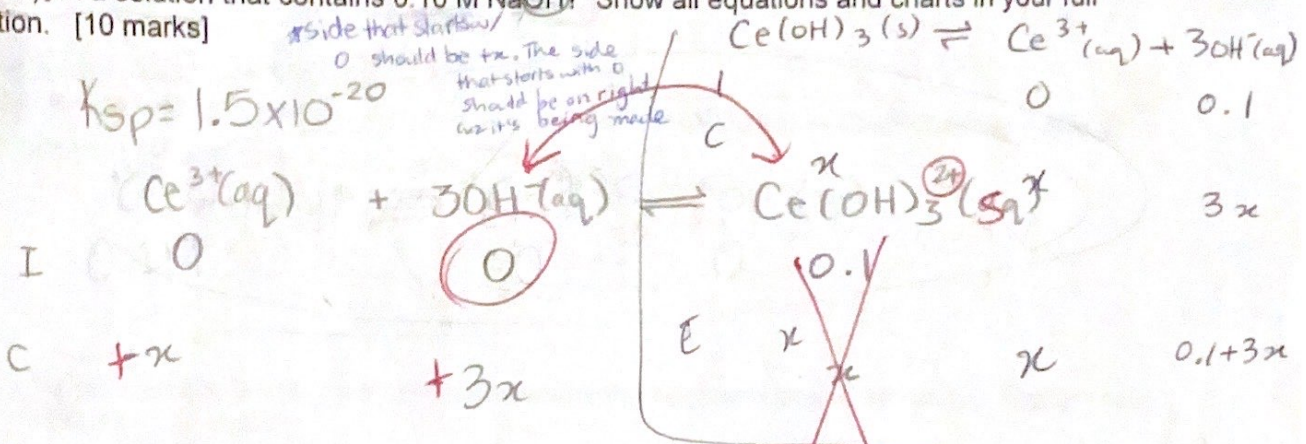
$[HCl] = 0.22 + 2(-0.01) = 0.2M$   
 $[Cl_2] = -(-0.01) = 0.01M$   
 $[H_2] = -(-0.01) = 0.01M$

↳ eq. [ ]

5  
(b)(ii)

The value of  $K_{sp}$  for cerium hydroxide,  $Ce(OH)_3$ , is  $1.5 \times 10^{-20}$ . 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]

mol/L



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

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

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

$1.5 \times 10^{-20} = \frac{(1.5 \times 10^{-20})(0.1)}{27} = x$

$x = 2.7 \times 10^{-6}$

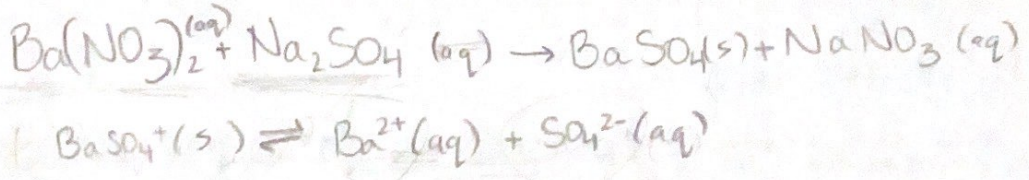
$K_{sp} = [Ce^{3+}][OH^-]^3$

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

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

$\therefore$  molar solubility is  $1.5 \times 10^{-17}$  mol/L of 0.10M NaOH(aq)

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



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

$(3.0 \times 10^{-3})(0.150L) = C_2(0.50)$

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

$Na_2SO_4 \quad C_1V_1 = C_2V_2$

$(5.0 \times 10^{-3}M)(0.350L) = C_2(0.50)$

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

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

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

$Q = (0.0009 M)(0.0035)$

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

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

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

$Q > K$

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