HW9 (16 questions)
LM13 & 14

UNIT 6 1/7/13

Concept of Equilibrium Concentrations
Law of Mass Action

Most missed question 7

A solution in equilibrium with sold barium phosphate is found to have a Barium ion concentration of 0.0005 M and Ksp of 3.4×10^{-23} Calculate concentration of phospate ion.

$Ba_3(PO_4)_2 \rightleftharpoons 3Ba^{2+} + 2PO_4^{3-}$

$3.4 \times 10^{-23} \quad [Ba^{2+}]^3 \; [PO_4^{3-}]^2$

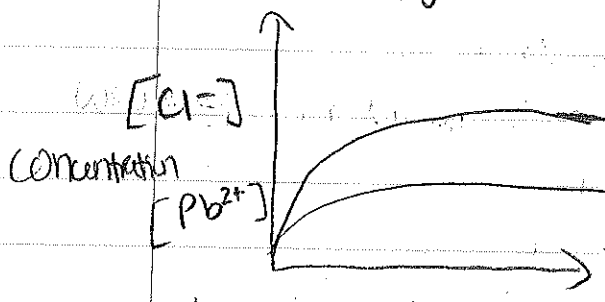
$3.4 \times 10^{-23} \quad [0.0005)^3 \; [X]^2$ → don't use 2x

$3.4 \times 10^{-23} = [0.0005)^3 \; [PO_4^{3-}]^2$

* Use 2x when you don't know any concentration of either ion.

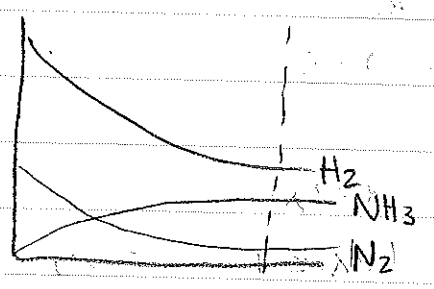
$[PO_4^{3-}] = \sqrt{\frac{3.4 \times 10^{-23}}{[0.0005]^3}}$

- Consider graphically $PbCl_2(s) \leftrightarrow Pb^{2+}(aq) + 2Cl^-(aq)$
  Plot change in concentration with time.



For every one of Pb^{2+} there's two Cl^- are made so the concentration is double.

Solid doesn't show up there because the concentrations of solid are none.



Write a chemical equation to describe what you see here?

Poll ↓

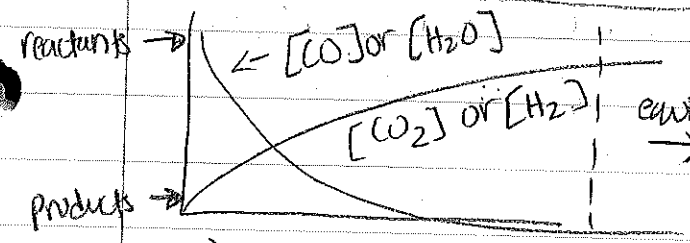
A) $N_2(g) + H_2(g) \leftrightarrow NH_3(g)$

B) $N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$

C) $N_2(g) + 3H_2(g) \leftrightarrow 2NH_3(g)$ ← at end of reaction

D. $2NH_3(g) \rightarrow N_2(g) + 3H_2(g)$

If is equilibrium. When concentration stop changing. Dynamic situation.



one line for 2 things because compounds changing at same rate.

$\begin{bmatrix} CO & CO \\ CO & H_2O & H_2O \\ CO & H_2O & H_2O \end{bmatrix} \rightarrow \begin{bmatrix} CO_2 H_2 & CO \\ CO_2 H_2 & H_2O \\ CO_2 H_2 & \end{bmatrix}$ ← More product than reactants.

Poll $3H_2(g) + N_2(g) \rightarrow 2NH_3(g)$

Imagine you start w/ 10mol of H_2 & 1mol N_2.

→ At equilibrium you find you have 1mole of NH_3 How many moles of H_2 are there at equilibrium?

10mol + 1mol → 1mol

$3H_2 + N_2 \rightarrow 2NH_3$

$1 \times \frac{3}{2} = \frac{3}{2}$

$10mol\ H_2 - \frac{3}{2} = 8.5\ mol\ H_2$

$\frac{1\ mol\ NH_3}{} \left| \frac{3\ H_2\ mol}{2\ NH_3\ mol} \right. = 1.5 mol$

initial	10
− used	−1.5
	8.5

8.5

Keeping it Right (R) ICE diagram.

	$3H_2(g)$	+ $N_2(g)$	$2NH_3(g)$	
I	10md H_2	1mol N_2	Ø	
C	$-3x$	$-x$	$+2x$	
E	$10-3x$	$1-x$	$2x = 1$	$x = .5$
	$10-3(0.5)$	$1-0.5$	$2(0.5)$	
	8.5			

The key idea

The ratios of molecule stop changing. We discover the ratio is a constant.

(K) = equilibrium constant

$K = \frac{a_C^{\ell} \cdot a_D^{m}}{a_A^{j} \cdot a_B^{k}}$ a = activity (amount of reactants & products molarity NP.

What is Activity? → related to how free energy is changing.

Solutions: for a soln this is concentration.

$a = \frac{[\ ]}{1M}$ Molar concentration.

(K is also unitless)

Gases: $a \frac{P_{gas}\ (atm)}{1atm\ (atm)}$ or $\frac{P_{gas}}{1bar}$ ← partial pressure. (not torr or psi).

Solid or Liquid $a = \underline{1}$ because pure solid or pure liquid free energy doesn't change.

$PbCl_2(s) \leftrightarrow Pb^{2+}(aq) + 2Cl^-(aq)$ ← write equilibrium.

$K = \frac{a_{Pb^{2+}}\ a_{Cl^-}^2}{a_{PbCl_2}} \quad \frac{\frac{[Pb^{2+}]}{1M} \cdot \frac{[Cl^-]^2}{1M^2}}{1} = [Pb^{2+}][Cl^-]^2$ $K_{sp} = a$

What is the expression for equilibrium constant for this reaction?

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

$K = \frac{\text{Products}}{\text{reactants}} \quad \frac{P_{NH_3}^2}{(P_{N_2})(P_{H_2})^3}$

- Law of Mass Action:

→ K is the ratio of concentration @ equilibrium of the products raised to stoichiometric coefficient divided by concentration of reactants at equilibrium.

* The value of K depends on how you have written the reaction and balanced the reaction.

- K in terms of Pressure K_p → gases can use either.

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

→ Express as $K_c = \frac{[NH_3]^2}{[N_2][H_2]^3}$ in soln

In K_c & K_p are diff values

→ Express as K_p $K_p = \frac{P_{NH_3}^2}{P_{N_2} P_{H_2}^3}$ use ideal gas law to derive relationship.

from free energy.

Equilibria ✓ Homogeneous - reactants & products are all in same phase (g)

Heterogeneous - reactants & products are in different phases (s) (aq).

What about water? → activity of pure water ≠ 1

$K = \frac{\text{Products}}{\text{reactants}}$

- K > 1 More products than reactants @ equilibrium "product favored"
- K < 1 more reactants than products @ equilibrium "reactant favored"

* Equilibrium does NOT depend on starting conditions. ratio is fixed, NO matter how much of something you start with, but K value is SAME.

• At equilibrium you find:
$[H_2] = .1M$, $[N_2] = 0.2M$, & $[NH_3] = .2M$.
$K = ?$

$3H_2(g) + N_2(g) \leftrightarrow 2NH_3(g)$ $K = \frac{[NH_3]^2}{[H_2]^3[N_2]} =$

$.1M + .2M \quad .2M$ $\frac{(0.2)^2}{(0.1)^3(0.2)} = 200.$

$K = 200$ & ↗ equilibrium ↘ ↗ initial concentration
$[H_2] = .2M$, $[N_2] = 0.4\ M$, & $C_{NH_3} = .1M$.

R	$3H_2(g) +$	$N_2(g) \leftrightarrow$	$2NH_3(g)$	
I	1.25	0.75	0.1	$0.1 + 2x = 0.8$
C	$-3x$ (-1.05)	Why neg: $-x$ (-0.35)	$+2x$ (.7)	$0.7 = 2x$
E	0.2	0.4	0.8	$x = 0.35$

$K = 200 = \frac{[NH_3]^2}{[.2]^3[.4]} =$

Typical Problem. $K = 200$

R	$3H_2(g) +$	$N_2(g) \leftrightarrow$	$2NH_3(g)$	
I	.2	0.2	Ø	$K = \frac{(2x)^2}{(0.2-3x)^3(0.2-x)}$
C	$-3x$	$-x$	$\leftrightarrow +2x$	
E	$0.2-3x$	$0.2-x$	$\leftrightarrow +2x$	200 $x = 0.045$

$x = 0.211$

wrong ans. you started w/ 0.2 and can't take away by it. ~~x = imaginary~~

Poll → What is change for H_2O?

	$2C_2H_6(g)$	+ $7C_2(g)$	⟷ $4CO_2(g)$	+ $6H_2O(g)$
R				
I	1.0	1.4	1.8	0
C	$-2x$	$-7x$	$+4x$	$\boxed{+6x}$
E	$1.0-2x$	$1.4-7x$	$1.8+4x$	$0+6x$