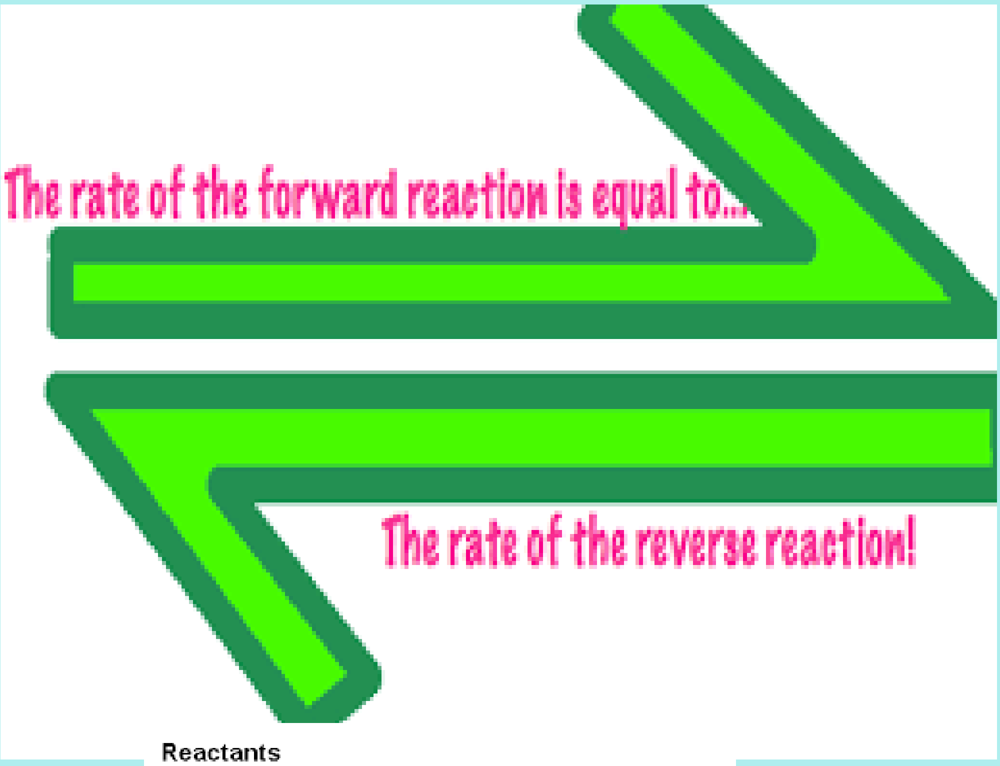
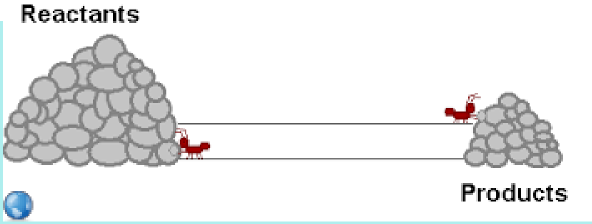
Chemical Equilibrium Constants





Objectives:

(#11-1) What is the difference between completion and equilibrium?

- I can represent a reaction going to equilibrium or to completion as a particulate model or graphically
- I can specifically model a solubility equilibrium system using particulate diagrams.

(#11-2) What is and why do we need a equilibrium constant?

- I can write an equilibrium constant expression Kc or Keq.
- I can write an equilibrium constant expression Kp (partial pressures)
- I can write an equilibrium constant expression for solubility Ksp.
- I can explain how the value of the equilibrium constant (K) relates to the extent of the reaction.
- I can calculate a new K value from an old K value if the reaction is altered (Altered means reversed or coefficients are a multiple of the original)

(#11-3)Can I fill out an ISE table?

- I can solve for an equilibrium concentration.
- I can solve for a k value given appropriate information.

(#11-4)How do I know how a reaction will proceed when approaching equilibrium?

- I can calculate a reaction quotient.
- I can relate reaction quotient to equilibrium constant to fudge how a reaction will proceed to get tot equilibrium
- I can determine if a stress (change) actually alters the equilibrium position.
- I can determine how the reaction will change if the reaction mixture was altered from equilibrium to get back to equilibrium (Le Chatelier's Principle.)

(#11-5) Modeling equilibrium

- I can model equilibrium using particulate drawings.

Apr 30-5:12 PM

Equilibrium Constant, K or K_{eq}

- constant for a specific reaction at a specific temperature.

(change T, then the K changes)

$K = \frac{[P]}{[R]}$

K_c
- **c**oncentrations are tracked
- use brackets [ ]
- Equilibrium Expression- only include **(aq) and (g)**
- (s) and (l) -- not included

$3A_{(g)} + B_{(aq)} \rightarrow 7C_{(s)} + 2D_{(g)}$

Eq Expression → $K_c = \frac{[D]^2}{[A]^3[B]^1}$

K_p
- **p**artial pressures are tracked
- use parentheses
- Equilibrium Expression- **only include gas**
- (aq), (s), and (l) -- not included
- Use PV=nRT with partial pressures

$K_p = \frac{(P_D)^2}{(P_A)^3} = \frac{(\quad)}{(\quad)}$

K_{sp}
- **s**olubility **p**roduct is tracked
- Equilibrium Expression- only include **(aq) and (g)**

> (s) and (l) -- not included

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

$K_{sp} = \frac{[Al^{+3}] \cdot [OH^-]^3}{1}$

Apr 30-7:30 PM

K_{sp} Solubility Product

temp. dependant

Table A-10

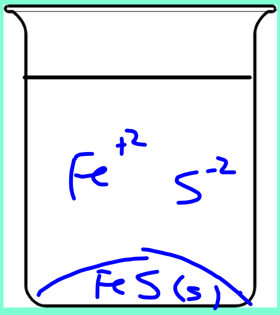
Solubility Product Constants (at 25°C)

Substance	K_{sp}	Substance	K_{sp}	Substance	K_{sp}
AgBr	7.70×10^{-13}	$BaSO_4$	1.08×10^{-10}	$MnCO_3$	1.82×10^{-11}
$AgBrO_3$	5.77×10^{-5}	$CaCO_3$	8.70×10^{-9}	$NiCO_3$	6.61×10^{-9}
Ag_2CO_3	6.15×10^{-12}	CdS	3.60×10^{-29}	$PbCl_2$	1.62×10^{-5}
AgCl	1.56×10^{-10}	$Cu(IO_3)_2$	1.40×10^{-7}	PbI_2	1.39×10^{-8}
Ag_2CrO_4	9.00×10^{-12}	CuC_2O_4	2.87×10^{-8}	$Pb(IO_3)_2$	2.60×10^{-13}
$Ag_2Cr_2O_7$	2.00×10^{-7}	FeC_2O_4	2.10×10^{-7}	$SrCO_3$	1.60×10^{-9}
AgI	1.50×10^{-16}	FeS	3.70×10^{-19}	TlBr	3.39×10^{-6}
AgSCN	1.16×10^{-12}	Hg_2SO_4	7.41×10^{-7}	$ZnCO_3$	1.45×10^{-11}
$Al(OH)_3$	1.26×10^{-33}	Li_2CO_3	1.70×10^{-2}	ZnS	1.20×10^{-23}
$BaCO_3$	8.10×10^{-8}	$MgCO_3$	2.60×10^{-5}		

Determine the M of each ion at 25°C

$FeS_{(s)} \rightarrow Fe^{+2}_{(aq)} + S^{-2}_{(aq)}$

I
S: $-x$ $+x$ $+x$
E



$K_{sp} = [Fe^{+2}]\cdot[S^{-2}] = 3.7\times10^{-19}$

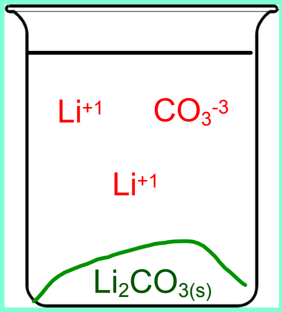
$x^2 = 3.7\times10^{-19}$

$x = 6.08\times10^{-10} = [Fe^{+2}] = [S^{-2}]$

$Li_2CO_{3(s)} \rightarrow 2Li^{+1} + CO_3^{-2}$

$K_{sp} = 1.7\times10^{-2} = [Li^{+}]^2\cdot[CO_3^{-2}]$ (2x, x)

$1.7\times10^{-2} = (2x)^2 \cdot x = 4x^3$



$x^3 = 0.00425$

$[CO_3^{-3}]$ = x = 0.16 M

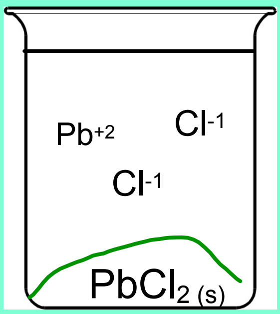
$[Li^{+1}]$ = 2x = 2 (0.16) = **0.32M**

Experimentally: At 39°C, the $[Pb^{+2}]$ = 1.8 E-4.

What is the K_{sp} for $PbCl_2$?

$PbCl_2 \rightarrow Pb^{+2} + 2Cl^{-1}$

I
C: $x - 1.8E{-4}$ $+1.8E{-4}$ $+2(1.8E{-4})$
E



$K_{sp} = [Pb^{+2}][Cl^-]^2 = (1.8E{-4})(3.6\times10^{-4})^2 = 2.3\times10^{-11}$

May 4-8:11 AM

Equilibrium Constant K

ratio of product to reactants at equilibrium

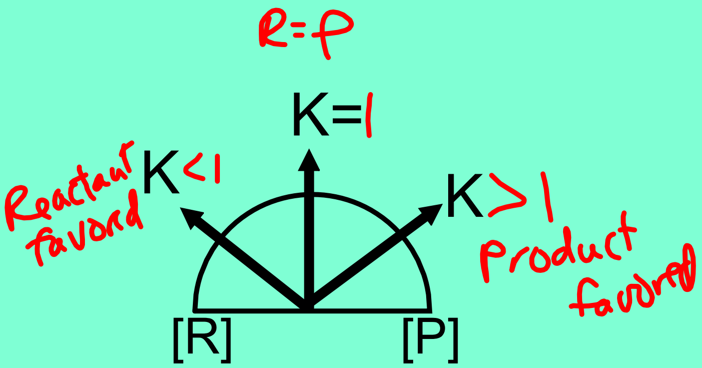
Reaction Quotient, Q

ratio of product to reactants at initial conditions

$$A_{(g)} + 2B_{(g)} \rightleftharpoons C_{(g)}$$

$$K_{eq} = \frac{[C]}{[A][B]^2}$$

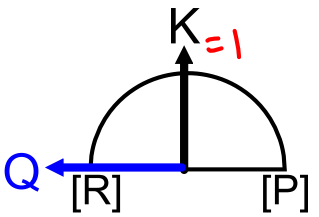
$$Q = \frac{[C]}{[A][B]^2}$$



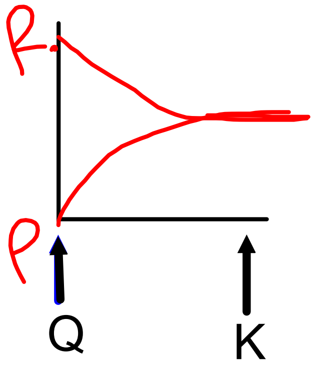
page 2 **Add in Q (Not on Worksheet)**

8.

Q (all reactants, no products)



[P] = [R]



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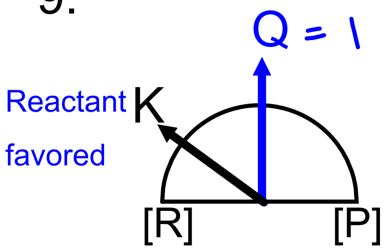

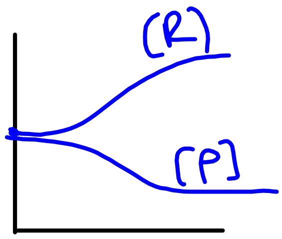

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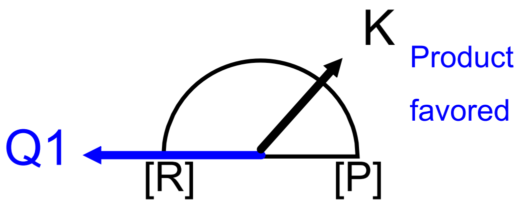

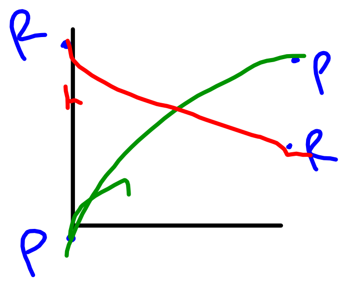

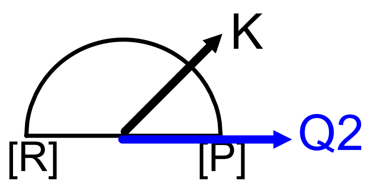

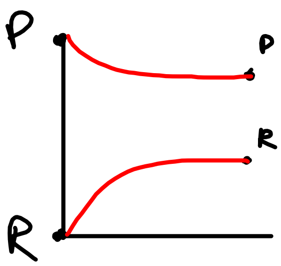

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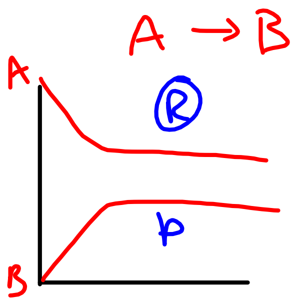
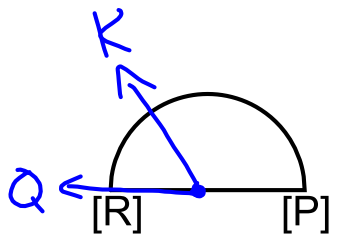
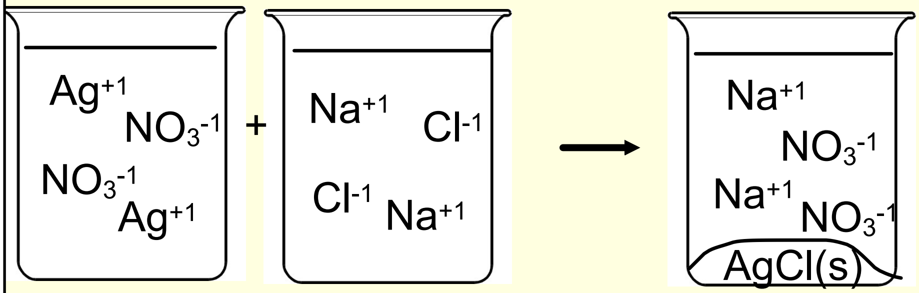




Ksp and Q Reaction quotient

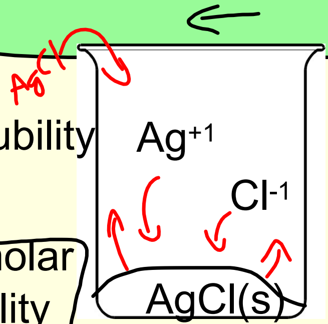
Examples:

$AgNO_3$ + NaCl ⟶ $AgCl_{(s)}$ + $NaNO_3$



net: Ag^{+1} + Cl^{-1} ⟶ $AgCl_{(s)}$ $K_{sp} = \frac{1}{[Ag^{+1}][Cl^{-1}]}$

Max. solubility → use molar solubility ← solubility in Molarity instead of g/100mL water



FLIP IT - for ***published*** K_{sp} table (used in industry)

$AgCl_{(s)}$ ⟶ Ag^{+1} + Cl^{-1} $K_{sp} = [Ag^{+1}][Cl^{-1}]$

K_{sp} = 1.8 E-10 at 25°C (from table)

Which is more soluble?

Compare K_{sp} of 2 salts:

AgCl:	K_{sp} = 1.8 E-10	less soluble
$Ca(OH)_2$	K_{sp} = 7 E-5	more soluble

For $Ca(OH)_2$, write the solubility reaction, K_{sp} expression, draw a model of dissolution, determine $[Ca^{+2}]$, $[OH^{-1}]$, and pH

K_{sp}= 7 E-5

Solubility Reaction

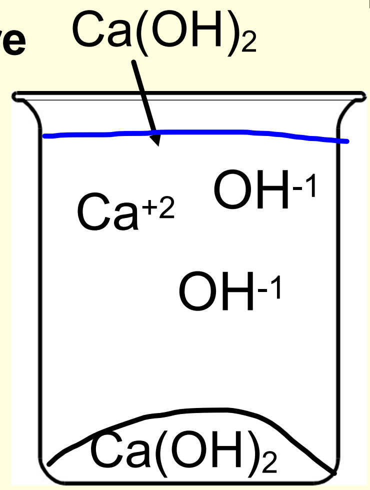
$$Ca(OH)_{2(s)} \longrightarrow Ca^{+2} + 2\ OH^{-1}$$

(always write the solid first for Ksp)

Ksp Expression

$$K_{sp} = \frac{[Ca^{+2}][OH^{-1}]^2}{1}$$

Picture



Initial:

Q= (0)(0) =0

$Ca(OH)_{2(s)} \longrightarrow$		Ca^{+2}	+ $2\ OH^{-1}$
I	-	0	0
S	-	+x	+2x
E	-	x	2x

$$K_{sp} = (x)(2x)^2 = 7\text{ E-5}$$

$$4x^3 = 7\text{ E-5}$$

$$x^3 = 1.75\text{ E-5}$$

(raise to 1/3 power to cancel cube)

$$(x^3)^{\frac{1}{3}} = (1.75\text{ E-5})^{\frac{1}{3}}$$

$$x=0.026$$

$[OH^{-1}]$=2x=2(0.026) =0.052

$[Ca^{+2}]$ = x =0.026

pOH**=** -log 0.052 =1.3

pH = 12.7