AP Chemistry – General (K_c, K_p) and Solubility (K_{sp}) Equilibrium

Equilibrium – rate of the forward rxn = rate of reverse rxn… Concentrations of products and reactants stay the same

Equilibrium Expressions

$$aA + bB \rightleftharpoons cC + dD$$

$$K_c = \frac{[C]^c [D]^d}{[A]^a [B]^b}$$

Trick alert:
only (aq) and (g) states go into equil. expressions

K>1   means more products than reactant
We say products are favored
[P]>[R] so ratio ($\frac{P}{R}$) BIGGER than 1

K<1   means more reactants than products
We say reactants are favored
[R]>[P] so ratio ($\frac{P}{R}$) SMALLER than 1

NEVER include pure substances in equilibrium expressions!

Leave out solids (s) and liquids (l)

Converting between K_c and K_p

$$K_p = K_c (RT)^{\Delta n}$$

Δn = diff in moles of gas (P-R)
---think predicting entropy---

When $\Delta n = 0$, K_c equals K_p

Pressures (K_p) – versus – Molarity (K_c)

Concentrations use K_c $K_c = \dfrac{[C]^c [D]^d}{[A]^a [B]^b}$

Pressures use K_p $K_p = \dfrac{(P_C)^c (P_D)^d}{(P_A)^a (P_B)^b}$

Trick alert: Watch out for parenthesis versus brackets!

Changing Rxns and Changing K

- *Multiply/divide rxns by n (K^n)*
(2x)   A $\rightleftharpoons$ B   (K) $\rightarrow$ 2A $\rightleftharpoons$ 2B   (K^2)

- *Reverse rxns ($\frac{1}{K}$)*
A $\rightleftharpoons$ B   (K) $\rightarrow$ B $\rightleftharpoons$ A   ($\frac{1}{K}$)

- *Law of summation (adding rxns)*
A $\rightleftharpoons$ C K_1
B $\rightleftharpoons$ D K_2

A + B $\rightleftharpoons$ C + D   ($K_1 \times K_2$)

Reaction Quotient (Q)

Describes ratio of products/reactants when not at equilibrium
- Can be used to predict which direction a reaction needs to go to get to equilibrium
Sets up just like K_c/K_p expressions

Q>K   too many products
$\frac{[P]}{[R]}$ ratio too big,
rxn goes reverse (to reduce P)

Q=K   perfect ratio, rxn at equil.

Q<K   too many reactants
$\frac{[P]}{[R]}$ ratio too small,
Rxn goes forward (to reduce R)

QCK Tables

QCK TABLES ARE USED TO SOLVE FOR EQUILIBRIUM VALUES

Basic set-up of QCK table:

Q – Given values (concentration or pressures)

C – determine change in X (pos/neg and don't forget coefficients)

K – equilibrium values (conc. or press.)

This is one of the most important calculations all year….

You must be able to do this!

LeChatelier's Principle

Used to Predict which direction rxns will go in response to changes
     *** Shift will ALWAYS nullify or "get rid of" change made***
Examples:
1.) add reactant – Rxn sifts towards products to consume added reactant
2.) Remove reactant – Rxn shifts towards reactants to replace reactant that was removed
Memory trick: Rxns always shift away from add and towards a reduction

Don't forget	Trick Alerts:
Endothermic (+ΔH) – heat is reactant	1.) inert substances DO NOT cause shift
Exothermic (-ΔH) – heat is product	2.) Catalysts DO NOT cause shift

Solubility Equilibrium (K_{sp}) – describes equilibrium established between slightly soluble salts and their dissociated ions

Solubility Reactions and K_{sp}

$$AB_{2\,(s)} \rightleftharpoons A^{+2}_{\ (aq)} + 2B^-_{\ (aq)}$$
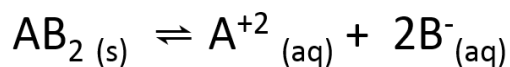
$$K_{sp} = [A^{+2}][B^-]^2$$

It is still: $K = \dfrac{[P]^m}{[R]^n}$

Remember we DO NOT INCLUDE solids….
So solid reactant left out of expression

Vocabulary Alert!

Solubility or Molar solubility is = x (mol/L)

Solubility product = K_{sp}

Calculating Solubility

- Solubility or Molar solubility refers to the amount of solid that has dissolved at equilibrium… it is equal to X (from QCK table)

$$AB_{2\,(s)} \rightleftharpoons A^{+2}_{\ (aq)} + 2B^-_{\ (aq)}$$

	A^{+2}	B^-
Q	0	0
C	x	2x
K	x	2x

$$K_{sp} = [A^{+2}][B^-]^2 = (x)(2x)^2 = 4x^3$$
$$K_{sp} = 4x^3$$
$$\text{(Solve for x!)}$$
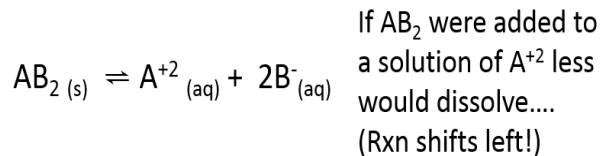
Reaction Quotient for K_{sp}

- Can be used to predict which direction a reaction needs to go to get to equilibrium

    Sets up just like $K_c/K_p/K_{sp}$ expressions

Q>K too many products, so solution supersaturated
rxn goes reverse (to reduce P), **precipitate will form**

Q=K perfect ratio, rxn at equilibrium, solution is **saturated**

Q<K too many reactants, so solution unsaturated
rxn goes forward, **more will dissolve**

Common Ion Effect

Common ions decrease solubility according to LeChatelier's principle

$$AB_{2\,(s)} \rightleftharpoons A^{+2}_{\ (aq)} + 2B^-_{\ (aq)}$$

If AB_2 were added to a solution of A^{+2} less would dissolve….
(Rxn shifts left!)

Trick alert: if you have a common ion [ ] you would use that [ ] as the initial [ ] in the QCK table

REMEMBER WE WILL IGNORE ANY PLUS/MINUS (X) IN EQUILIBRIUM ROW OF QCK TABLES ON THE AP TEST!!!

Selective Precipitation

If you are asked about which species will precipitate out of solution 1st you must compare molar solubilities

    *** The LOWER molar solubility will precipitate 1st ***

Trick alert: please remember that all substances are slightly soluble. If a ppt does form then you need to use K_{sp} to determine concentrations of dissociated ions once precipitation is complete (this might also have common ion effect as well)

These problems can be tricky and require a high level of understanding of K_{sp} equilibrium calculations!

    With practice these become easy!

Vocabulary Alert!

Solubility or Molar solubility is = x (mol/L)

Solubility product = K_{sp}

Solubility and pH

If H^+ or OH^- is a product of dissolution, solubility will be affected by acidic or basic conditions

Base/acid react to form water (it is a common ion effect problem!)

Helpful K_{sp} Ratios

1:1 $K_{sp} = x^2$

1:2 $K_{sp} = 4x^3$

1:3 $K_{sp} = 27x^4$

2:3 $K_{sp} = 108x^5$