Equilibrium / Acid-Base Intro

Name: _____

AP Chemistry Lecture Outline

Video 1503 (9:03)

reversible reaction: AND

Acid ionization is a reversible reaction. $HNO_2 \rightleftharpoons H^+ + NO_2^-$

equilibrium:

Equilibrium is reached when the concentrations of reactants and products cease changing w/time. **reactants** $\rightleftharpoons$ **products**

-- system must be closed

--

For the reaction A $\rightleftharpoons$ B:

-- Eq. can be reached starting with…

Video 1506 (9:12)

law of mass action: the observation that the rate of a chemical rxn is proportional to the product of the amounts of substances on one side of a chemical equation, raised to the power of their coefficients

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For the equilibrium system $aA + bB \rightleftharpoons pP + qQ$ the law of mass action says that an equilibrium constant K is given by:

When amts. are given in terms of concentration (i.e., molarity):

For a gaseous system: where P_X is the partial pressure of X

at eq., and K_p is the pressure eq. constant

Video 1509 (8:09)

Points about the value of K:

-- It is independent of initial concentrations.

-- It varies with temp.

-- It is written without units.

Points about the equilibrium-constant expression:

-- It NEVER includes pure liquids or solids.

-- It depends ONLY on the rxn stoichiometry.

EX. For the gaseous reaction

$2\ NO + O_2 \rightleftharpoons 2\ NO_2$

write the K_c and K_p expressions.

Now for this reaction...

$2\ NO_2 \rightleftharpoons 2\ NO + O_2$

-- When writing an eq-constant expression, you must refer to a...

-- The K for the forward and reverse reactions are NOT the same;

EX. Write the equilibrium-constant expressions for K_c.

$SnO_2(s) + 2\ CO(g) \rightleftharpoons Sn(s) + 2\ CO_2(g)$

$\frac{1}{2}\ SnO_2(s) + CO(g) \rightleftharpoons \frac{1}{2}\ Sn(s) + CO_2(g)$

The Magnitude of the Equilibrium Constant

If K >> 1... ...we have LOTS of _____. We say "_____ are favored" and that the equilibrium "lies to the _____."

If K << 1... ...we have LOTS of _____. We say "_____ are

favored" and that the equilibrium "lies to the _____."

Video 1512 (7:48)

Calculations with Equilibrium Constants

(1) If we know *equilibrium amounts*, we just plug and chug to find our unknown.

EX. Find K_c @ 472°C for $N_2(g) + 3\,H_2(g) \rightleftharpoons 2\,NH_3(g)$

At equilibruim @ 472°C,

$[NH_3] = 0.00272$ M,

$[N_2] = 0.0402$ M,

$[H_2] = 0.1207$ M.

EX. For $PCl_5(g) \rightleftharpoons PCl_3(g) + Cl_2(g)$, $K_p = 0.497$ at 500 K. At eq., the partial pressures of PCl_5 and PCl_3 are 0.860 atm and 0.350 atm, respectively. Find the partial pressure of Cl_2.

(2) If we know *initial amounts*, then make an ICE chart and use rxn stoichiometry to determine equilibrium amounts. THEN plug and chug.

EX. At 1000 K, the amounts shown below are known. Find K_c @ 1000 K.

	$2\,SO_3(g) \rightleftharpoons$	$2\,SO_2(g)$	+	$O_2(g)$
initial	**6.09×10^{-3} M**	**0 M**		**0 M**
Δ				
at eq.	**2.44×10^{-3} M**			

Video 1515 (4:12)

EX. For the rxn below, $K_p = 0.497$ at 500 K. If an otherwise-empty gas cylinder is charged with PCl_5 at 1.660 atm at 500 K, find the partial pres. of all substances at eq.

	$PCl_5(g) \rightleftharpoons$	$PCl_3(g)$	+	$Cl_2(g)$
Initial	**1.66 atm**	**0 atm**		**0 atm**
Δ				
at eq.				

Video 1518 (6:01)

By knowing K and amts. of Rs and Ps at any particular time, we can predict...

i.e.,

<u>reaction quotient, Q</u>: what you get when you plug the R and P amts. ***at any given time*** into the eq.-constant expression

If Q > K...

If Q < K...

If Q = K...

EX. For $H_2(g) + I_2(g) \rightleftharpoons 2\,HI(g)$, $K_c = 51$ at a temp. of 488°C. If you start with 0.020 mol HI, 0.010 mol H_2, and 0.030 mol I_2 in a 2.0-L container, which way will the reaction proceed?

Video 1521 (8:50)

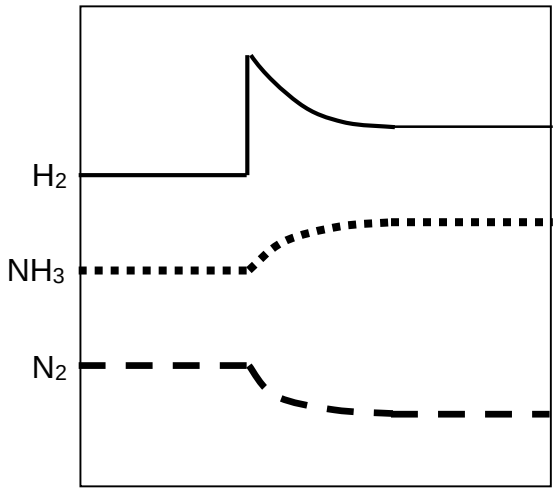
<u>Le Chatelier's Principle</u>: "If a system at equilibrium is disturbed by a change in temperature, pressure, or concentration of a component, the system will shift its equilibrium position to counteract the effect of the disturbance."

(A) *change in concentration*

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

Disturbance	***Equilibrium Shift***
Add more N_2.....	
Add more H_2.....	
Add more NH_3.....	
Remove NH_3.....	

Diagram shows what happens when we add H_2 to an equilibrium system...



(B) *effect of a catalyst*

-- the forward and reverse reaction rates are both increased

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Video 1524 (7:01)

(C) *changes in pressure or volume*

$2\ NO_2(g) \rightleftharpoons N_2O_4(g)$

If we increase pressure, the system "wants" to...

If we decrease pressure, the system "wants" to...

For $H_2(g) + I_2(g) \rightleftharpoons 2\ HI(g)$, pressure changes result in...

More specifically, if the partial pressures are affected, then there will be shifting. Otherwise...no.

e.g., $2\ SO_2(g) + O_2(g) \rightleftharpoons 2\ SO_3(g)$

If we add neon into reaction vessel...

As long as temperature doesn't change, K is...

Video 1527 (9:00)

(D) *changes in temperature*

These always result in...

For exothermic reactions: R ⇌ P (ΔH is ____)

-- as T increases...

-- as T decreases...

For endothermic reactions: R ⇌ P (ΔH is ____)

-- as T increases...

-- as T decreases...

Q: "Is this related to transition lenses?"

$AgCl + \text{energy} \rightleftharpoons Ag^o + Cl^o$
(clear) (dark)

Go outside... Then go inside...

Summary: Le Chatelier's Principle

EX. $PCl_5(g) \rightleftharpoons PCl_3(g) + Cl_2(g)$ $\Delta H^o = 87.9$ kJ

Predict shifts.

(a) add Cl_2 (c) increase pressure

(b) remove PCl_3 (d) increase temperature

Video 1530 (8:30)

Acids and Bases: Introductory Concepts

Arrhenius ...acids increase the _____ when dissolved in H_2O.

...bases increase the _____when dissolved in H_2O.

e.g., HCl and NaOH

--

Bronsted-Lowry acids:

Bronsted-Lowry bases:

-- H^+ and H_3O^+ are used interchangeably

-- B-L concept is NOT limited to aqueous solutions

Arrhenius and Bronsted-Lowry definitions overlap, in many cases.

$$NH_3(aq) + H_2O(l) \rightleftharpoons NH_4^+(aq) + OH^-(aq)$$

One substance can't be a Bronsted-Lowry acid unless...

-- the acid must be able to lose H^+

-- the base must have a nonbonding pair of e^- that can bind with the H^+

Video 1533 (9:23)

<u>Amphoteric</u> substances can be acids or bases, depending on the reaction conditions.

$$HCl(aq) + H_2O(l) \rightleftharpoons$$

$$NH_3(aq) + H_2O(l) \rightleftharpoons$$

NH_3 is another example. When a B-L acid, it morphs into on the P side.

" " " base, " " " " " " " " .

** In acid-base equilibria, protons are simultaneously transferred in forward and rev. rxns...

-- The two substances in a <u>conjugate acid-base pair</u> differ by a H^+...

EX. $HNO_2(aq) + H_2O(l) \rightleftharpoons NO_2^-(aq) + H_3O^+(aq)$

-- Strong [acids] / bases "100%" [ ] / _____ H^+.

-- Weak [acids] / bases "tiny %" [ ] / _____ H^+.

-- The stronger a/n [acid] / base...

HCl HF

In every acid-base rxn, the position of eq. favors the transfer of H^+ from stronger acid to stronger base.

Video 1536 (5:33)

The Autoionization of Water

In water, we constantly have (a little)... $H_2O(l) + H_2O(l) \rightleftharpoons H_3O^+(aq) + OH^-(aq)$

Thus (@ 25°C), the equilibrium constant for water is:

This equation is taken to be valid for pure water and for dilute aqueous solutions, @ 25°C.

$[H^+] > [OH^-]$ $[H^+] < [OH^-]$ $[H^+] = [OH^-]$

_____ _____ _____

EX. At 25°C, calculate the hydrogen ion concentration if the hydroxide ion concentration is 2.7×10^{-4} M. Is this solution an acid or a base?

Video 1539 (10:41)

The pH Scale

Definition of pH... **0 ACID 7 BASE 14**

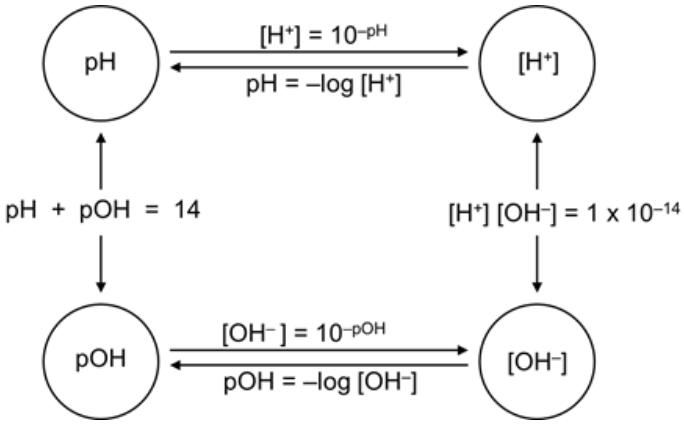
--

A change of 1 pH unit means that $[H^+]$ (and $[OH^-]$) has changed by a factor of _____.

EX. A solution with pH 2 is how many times more acidic than one with pH 5?

Other equations:

Mr. B's pH Island Diagram



** Significant figures rule for logarithms:

EX. If the pH = 4.87, find the hydronium ion concentration.

Video 1540 (5:35)

EX. If the hydroxide ion concentration is 5.6×10^{-11} M, find the pH.

Video 1542 (3:34)

Measuring pH

pH meter

<u>acid-base indicators</u>:

e.g.,

<u>pH paper</u> is paper impregnated with mixtures of various indicators.

Video 1545 (6:23)

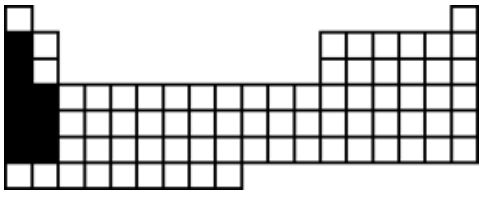
Strong Acids and Bases

-- these are strong electrolytes that exist entirely as ions in aqueous solution

-- <u>Memorize</u> the names and formulas of the seven strong acids...

...and the eight strong, hydroxide bases...

hydrochloric, HCl
hydrobromic, HBr
chloric, $HClO_3$
hydroiodic, HI
perchloric, $HClO_4$
nitric, HNO_3
sulfuric, H_2SO_4



Strong electrolytes are often written using a one-sided arrow.

e.g., $HNO_3(aq) \longrightarrow H^+(aq) + NO_3^-(aq)$

EX. Find the pH of a 0.012 M perchloric acid solution.

EX. If a nitric acid solution has pH = 2.66, find its concentration.

Video 1548 (3:42)

** NOTE: $Ca(OH)_2$, $Sr(OH)_2$, and $Ba(OH)_2$ are strong electrolytes, but have limited solubilities. This means that if you put a big chunk of any of these into water, little of the chunk will dissolve, BUT the little that does dissolve will float around as $X^{2+}(aq)$ and $OH^-(aq)$, NOT as $X(OH)_2(aq)$.

EX. Find the pH of a 0.0034 M soln of calcium hydroxide.