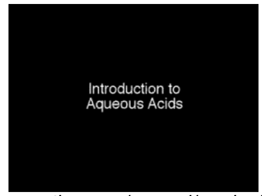
Acid-Base Equilibrium

Dr. Ron Rusay

https://www.youtube.com/watch?v=l5fk7HPmo5g

Introduction to Aqueous Acids

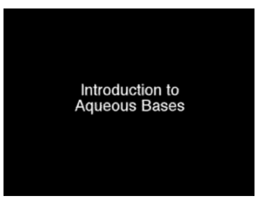
- Acids: taste sour and cause certain dyes to change color.



http://chemconnections.org/general/movies/acid-intro.mov

Introduction to Aqueous Bases

- Bases: taste bitter, feel soapy and cause certain dyes to turn color.



http://chemconnections.org/general/movies/Bases-intro.mov

Models of Acids and Bases

- Acids are H^+ donors & bases include all proton acceptors and are not limited to hydroxide ion $(OH)^-$
- $\underset{\text{acid}}{HCl} + \underset{\text{base}}{H_2O} \rightarrow Cl^- + H_3O^+$

Conjugate Acid/Base Pairs

- $\underset{\text{acid 1}}{HA(aq)} + \underset{\text{base 2}}{H_2O(l)} \rightarrow \underset{\text{conj acid 2}}{H_3O^+(aq)} + \underset{\text{conj base 1}}{A^-(aq)}$
- conjugate acid: formed when the proton is transferred to the base.
- conjugate base: everything that remains of the acid molecule after a proton is lost.

Equilibrium Constant (K_a)

- $HA(aq) + H_2O(l) \leftrightarrows H_3O^+(aq) + A^-(aq)$

$$K_a = \frac{[H_3O^+][A^-]}{[HA]} = \frac{[H^+][A^-]}{[HA]}$$

- $HA(aq) \leftrightarrows H^+(aq) + A^-(aq)$

Acid Strength

Strong Acid:

- Equilibrium position lies far to the right. (HNO_3); $K_a >> 1$

Acid Strength

Strong Acids:

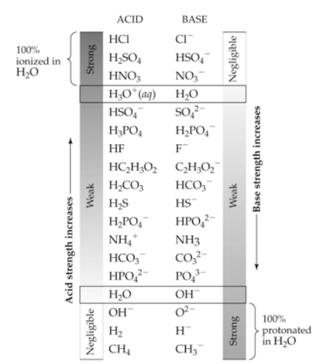
Strong Acid	Formula
Hydrochloric	HCl
Hydrobromic	HBr
Hydroiodic	HI
Nitric	HNO_3
Chloric	$HClO_3$
Perchloric	$HClO_4$
Sulfuric *	$\boxed{H_2SO_4}$

Acid Strength

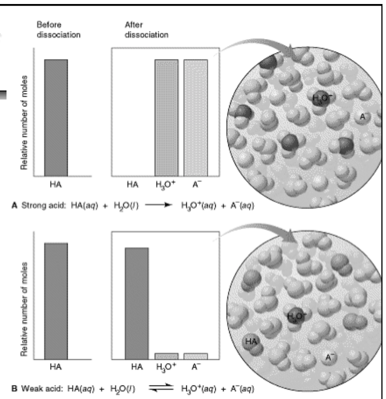
(continued)

Weak Acid:

- Equilibrium lies far to the left. (CH_3COOH); $K_a < 1$



The Extent of Dissociation for Strong and Weak Acids



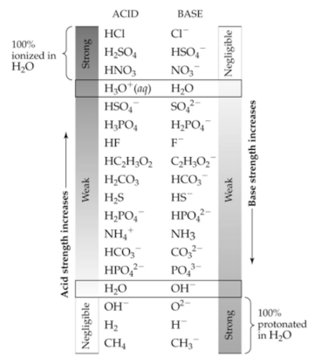
QUESTION

Nitric acid, HNO_3, is considered to be a strong acid whereas nitrous acid, HNO_2, is considered to be a weak acid. Which of the statements here is fully correct?

A. Nitric acid has an aqueous equilibrium that lies far to the right and NO_3^- is considered a weak conjugate base.
B. Nitric acid has a stronger conjugate base than nitrous acid.
C. The dissociation of nitrous acid compared to an equal concentration of nitric acid produces more H^+.
D. The equilibrium of nitrous acid lies far to the left and the conjugate base is weaker than the conjugate base of nitric acid.

ANSWER

A) correctly compares equilibrium and conjugate base characteristics. The conjugate base of a strong acid is considered to be weak. The stronger the acid, the more reaction in water. Therefore, a weak acid's equilibrium is favored to the left.



Bases

- *"Strong" and "weak" are used in the same sense for bases as for acids.*
- *Strong = complete dissociation, $K_b >> 1$ (concentration of hydroxide ion in solution)*

  $NaOH(s) \rightarrow Na^+(aq) + OH^-(aq)$
- $NaOH(s) + H_2O(l) \rightarrow Na^+(aq) + OH^-(aq)$

Bases
(continued)

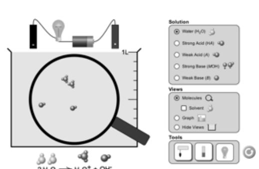
- *Weak bases have very little dissociation, $K_b < 1$ (little ionization with water)*
- $CH_3NH_2(aq) + H_2O(l) \leftrightarrows CH_3NH_3^+(aq) + OH^-(aq)$
- *How conductive is NaOH(aq) vs morphine, $C_{17}H_{19}NO_3$ (aq)?*

Acid-Base Strengths

http://phet.colorado.edu/sims/html/acid-base-solutions/latest/acid-base-solutions_en.html

Strong Acid:

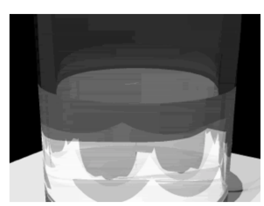
Strong Base:



Weak Acid:

Weak Base:

Water as an Acid and a Base
Self-ionization



http://chemconnections.org/general/movies/H2O-ionz.MOV

Water as an Acid and a Base

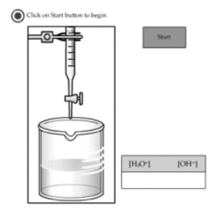
$$H_2O(l) + H_2O(l) \rightleftharpoons H_3O^+(aq) + OH^-(aq)$$

- *Water is amphoteric (it can behave either as an acid or a base).*
  - *$H_2O + H_2O \leftrightarrows H_3O^+ + OH^-$*

    acid 1 base 2 conj acid 2 conj base 1
  - *$K_w = 1 \times 10^{-14}$ at 25°C*

Water as an Acid and a Base

Self-ionization



http://chemconnections.org/general/movies/KwActivity.swf

The pH Scale

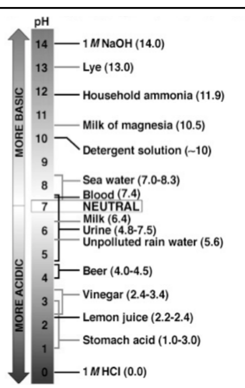
- *$pH \approx -\log[H^+] \approx -\log[H_3O^+]$*
- *pH in water ranges from 0 to 14.*

  $K_w = 1.00 \times 10^{-14} = [H^+][OH^-]$

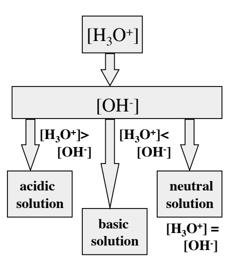
  $pK_w = 14.00 = pH + pOH$
- *As pH rises, pOH falls (sum = 14.00).*
- *There are no theoretical limits on the values of pH or pOH. (e.g. pH of 2.0 M HCl is -0.301)*

The Relations Among $[H_3O^+]$, pH, $[OH^-]$, and pOH

		$[H_3O^+]$	pH	$[OH^-]$	pOH
MORE BASIC	BASIC	1.0×10^{-15}	15.00	1.0×10^{1}	−1.00
		1.0×10^{-14}	14.00	1.0×10^{0}	0.00
		1.0×10^{-13}	13.00	1.0×10^{-1}	1.00
		1.0×10^{-12}	12.00	1.0×10^{-2}	2.00
		1.0×10^{-11}	11.00	1.0×10^{-3}	3.00
		1.0×10^{-10}	10.00	1.0×10^{-4}	4.00
		1.0×10^{-9}	9.00	1.0×10^{-5}	5.00
		1.0×10^{-8}	8.00	1.0×10^{-6}	6.00
	NEUTRAL	1.0×10^{-7}	7.00	1.0×10^{-7}	7.00
MORE ACIDIC	ACIDIC	1.0×10^{-6}	6.00	1.0×10^{-8}	8.00
		1.0×10^{-5}	5.00	1.0×10^{-9}	9.00
		1.0×10^{-4}	4.00	1.0×10^{-10}	10.00
		1.0×10^{-3}	3.00	1.0×10^{-11}	11.00
		1.0×10^{-2}	2.00	1.0×10^{-12}	12.00
		1.0×10^{-1}	1.00	1.0×10^{-13}	13.00
		1.0×10^{0}	0.00	1.0×10^{-14}	14.00
		1.0×10^{1}	−1.00	1.0×10^{-15}	15.00



The pH Values of Some Familiar Aqueous Solutions



QUESTION

In an aqueous solution at a particular temperature the $[H^+]$ was measured as 1×10^{-6} M. What is the $[OH^-]$ in the same solution? Is the solution acidic, basic, or neutral?

A. 1×10^{-20} *M*; acidic
B. 1×10^{-8} *M*; acidic
C. 1×10^{-6} *M*; basic
D. 1×10^{-8} *M*; basic
E. 1×10^{-7} *M*; neutral

Answer

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E. 1×10^{-7} *M*; neutral

$K_w = [H^+][OH^-] = 1.0 \times 10^{-14}$

QUESTION

An environmental chemist obtains a sample of rainwater near a large industrial city. The $[H^+]$ was determined to be 3.5×10^{-6} *M*. What is the pH, pOH, and $[OH^-]$ of the solution?

A. pH = 5.46 ; pOH = 8.54; $[OH^-] = 7.0 \times 10^{-6}$ *M*
B. pH = 5.46 ; pOH = 8.54; $[OH^-] = 2.9 \times 10^{-9}$ *M*
C. pH = 12.56 ; pOH =1.44 ; $[OH^-] = 3.6 \times 10^{-2}$ *M*
D. pH = 8.54; pOH = 5.46; $[OH^-] = 2.9 \times 10^{-9}$ *M*

Refer to:
http://chemconnections.org/general/chem106/Acids%20and%20Bases-WKS-2016.pdf
https://phet.colorado.edu/sims/html/ph-scale/latest/ph-scale_en.html

Answer

pH = –log$[H^+]$ can be used to find the pH then: 14.00 = pH + pOH can be used to obtain the pOH. Finally, $[OH^-] = 10^{-pOH}$

A. pH = 5.46 ; pOH = 8.54; $[OH^-] = 7.0 \times 10^{-6}$ *M*
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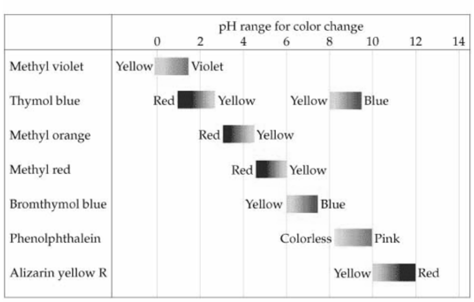
Indicators

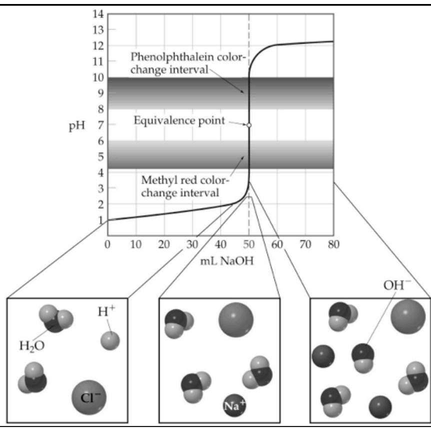
http://chemconnections.org/public_html/general/movies/indicators.MOV

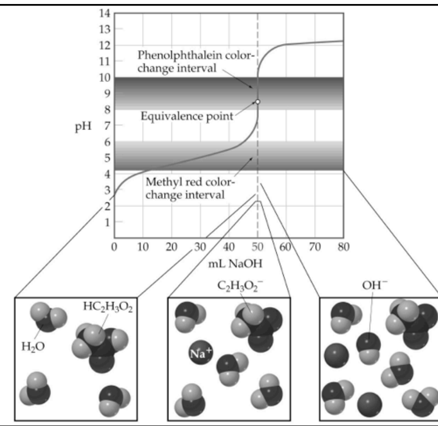
Acid-Base Indicators



Titrations: Indicators & (pH) Curves

- *pH Curve is a plot of pH of the solution being analyzed as a function of the amount of titrant added.*
- *Equivalence (stoichiometric) point: Enough titrant has been added to react exactly with the solution being analyzed. An indicator provides a visible color change to determine an (end point) volume of titrant.*

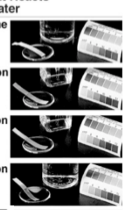




Behavior of Salts in Water

The Behavior of Salts in Water

Salt Solution (Examples)	pH	Nature of Ions	Ion That Reacts with Water
Neutral [NaCl, KBr, $Ba(NO_3)_2$]	7.0	Cation of strong base; Anion of strong acid	None
Acidic [NH_4Cl, NH_4NO_3, CH_3NH_3Br]	<7.0	Cation of weak base; Anion of strong acid	Cation
Acidic [$Al(NO_3)_3$, $CrCl_3$, $FeBr_3$]	<7.0	Small, highly charged cation; Anion of strong acid	Cation
Basic [CH_3COONa, KF, Na_2CO_3]	>7.0	Cation of strong base; Anion of weak acid	Anion

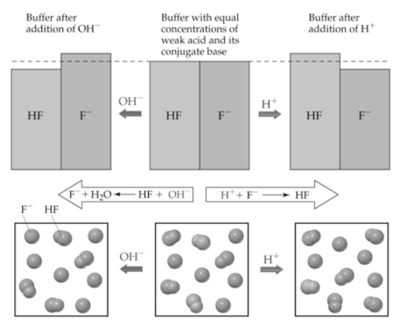


$LiNO_2$ NH_4Cl $Ca(NO_3)_2$

http://chemconnections.org/general/movies/pHofSaltSolutions.swf

$MgSO_4$ $AgClO_3$ CsCN

Buffer Systems



$H_2CO_3(aq)$ / $HCO_3^{-1}(aq)$ / $CO_3^{-2}(aq)$

Two VERY IMPORTANT Complex

Bicarbonate Buffer Systems

$$CO_2(g) + H_2O\ (l) \leftrightarrows HCO_3^{-1}(aq) + H^{+1}(aq) \leftrightarrows CO_3^{-2}(aq) + H^{+1}(aq)$$

1. *Blood: a human's blood serum volume is relatively small, 4-6 Liters. pH = 7.35 – 7.45 (homeostasis)*
   - *Ever had respiratory alkalosis?*

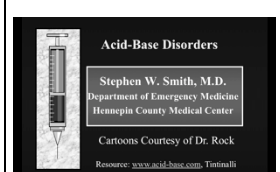
2.Oceans: an extraordinarily large volume "salt water" solution. pH = 8.1 and falling

http://www.tos.org/oceanography/issues/issue_archive/22_4.html

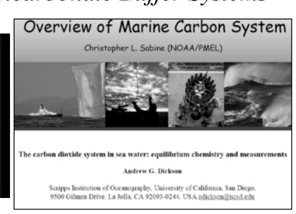
- *Increasing CO_2, decreasing ocean pH, long term effects? Coral reefs?*

http://sos.noaa.gov/datasets/Ocean/ocean_acidification.html

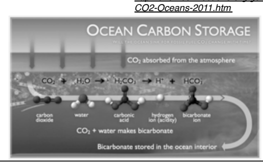
Human & Oceanic Bicarbonate Buffer Systems



http://chemconnections.org/general/chem121/Buffers/Buffers-Med-Pres.htm



http://chemconnections.org/general/chem121/Buffers/Buffers-CO2-Oceans-2011.htm

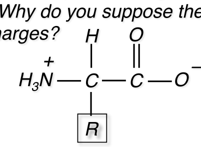


Buffers

http://chemconnections.org/general/movies/buffer.MOV

Amino Acids

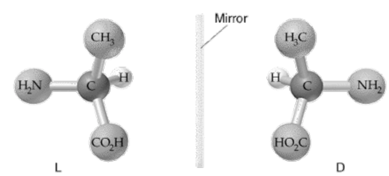
- More than 700 amino acids occur naturally, but 20 (22?) of them are especially important.
- These 20 amino acids are the building blocks of proteins in humans and developed organisms
- They differ in respect to the group attached to the α carbon. Why do you suppose they are written with + and – charges?



Amino Acids

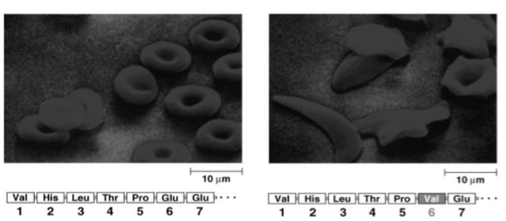
- Our bodies can synthesize about 10 amino acids.
- Essential amino acids are the other 10 amino acids, which have to be ingested.
- The α-carbon in all amino acids except glycine is chiral (has 4 different groups attached to it).
- Chiral molecules exist as two non-superimposable mirror images called enantiomers.
- L-amino acids are the common natural enantiomers.

Amino Acids



- L-amino acids are the common natural enantiomers, eg. Alanine above.

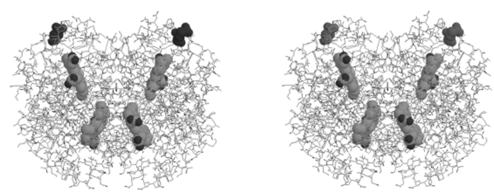
Sickle Cell Anemia
Normal hemoglobin vs sickle cell hemoglobin



(a) Normal red blood cells and the primary structure of normal hemoglobin

(b) Sickled red blood cells and the primary structure of sickle-cell hemoglobin

Sickle Cell Anemia
Normal hemoglobin vs sickle cell hemoglobin



Valine replaces Glutamate

http://chemconnections.org/Presentations/Columbia/slide9-3.html