Today

- 17.4 Equilibrium constants for Acids and Bases
- 17.5 Equilibrium constants and Acid-Base Reactions
- 17.6 Types of Acid-Base Reactions
- 17.7 Calculations

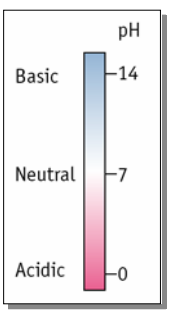
Neutral pH at different Temperatures

- K_w = 1.01 10^{-14} at 25 °C, neutral pH = 7.0
- K_w increase when T increase→
  T > 25 °C, neutral pH < 7.0
  T < 25 °C, neutral pH > 7.0

°C	K_w
10	0.29×10^{-14}
15	0.45×10^{-14}
20	0.68×10^{-14}
25	1.01×10^{-14}
30	1.47×10^{-14}
50	5.48×10^{-14}

Recommended: Simulation 17.3a

How can we define the strengths of acids and bases?



Higher the pH → the stronger the base

Strong BASE [OH⁻] = [BASE]
Weak BASE [OH⁻] << [BASE]

Weak ACID [H₃O⁺] << [ACID]
Strong ACID [H₃O⁺] = [ACID]

Lower the pH → the stronger the acid

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Relative strength of an acid and a base

- HA (aq) + H_2O (l) ⇆ H_3O^+ (aq) + A^- (aq)

$$K_a = [H_3O^+][A^-] / [HA]$$

- B (aq) + H_2O (l) ⇆ BH^+ (aq) + OH^- (aq)

$$K_b = [BH^+][OH^-] / [B]$$

List of strong acid and bases: page 810 Kotz

Get familiar with this Table

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We need to know:

$$K_A = \frac{[A^-][H_3O^+]}{[HA]}$$ Acid Ionization Constant

$$K_B = \frac{[BH^+][OH^-]}{[B]}$$ Base Ionization Constant

$$K_W = [H_3O^+][OH^-]$$ Water Auto-ionization Constant

pX = -logX

$K_W = K_A K_B$ $pK_W = pK_A + pK_B$

$-\log K_W = -\log(K_A \cdot K_B) = -\log K_A - \log K_B$

$pK_W = pK_A + pK_B$

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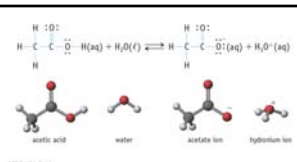
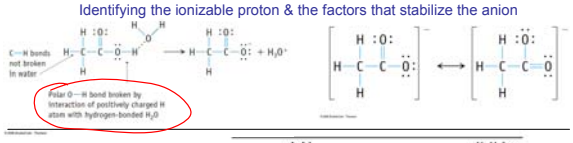
Ionization of Acetic Acid,
A weak acid
K_A = 1.8 x 10^{-5}



Identifying the ionizable proton & the factors that stabilize the anion



Problem 1: Calculate K_B from pK_A

Acid		pK_a Value
CH_3CO_2H	Acetic acid	4.74
$ClCH_2CO_2H$	Chloroacetic acid	2.85
Cl_2CHCO_2H	Dichloracetic acid	1.49
Cl_3CCO_2H	Trichloroacetic acid	0.7

increasing acid strength

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Calculating K_B from pK_A

Practical Point: Two different paths to the same result gives a way to test the validity of your answer.

Method 1: (a) Convert pK_A to K_A
(b) Calculate K_B as $K_B = K_W/K_A$

Method 2: (a) Calculate pK_B as pK_B = pK_W – pK_A
(b) Convert pK_B to K_B

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Table 17.3 Check it out on page 702 in Kotz. Ques.: What does K_AK_B equal?

Increasing Acid Strength

Increasing Base Strength

Table 17.3 • Ionization Constants for Some Acids and Their Conjugate Bases

Acid Name	Acid	K_a	Base	K_b	Base Name
Perchloric acid	$HClO_4$	large	ClO_4^-	very small	perchlorate ion
Sulfuric acid	H_2SO_4	large	HSO_4^-	very small	hydrogen sulfate ion
Hydrochloric acid	HCl	large	Cl^-	very small	chloride ion
Nitric acid	HNO_3	large	NO_3^-	very small	nitrate ion
Hydronium ion	H_3O^+	1.0	H_2O	1.0×10^{-14}	water
Sulfurous acid	H_2SO_3	1.2×10^{-2}	HSO_3^-	8.3×10^{-13}	hydrogen sulfite ion
Hydrogen sulfate ion	HSO_4^-	1.2×10^{-2}	SO_4^{2-}	8.3×10^{-13}	sulfate ion
Phosphoric acid	H_3PO_4	7.5×10^{-3}	$H_2PO_4^-$	1.3×10^{-12}	dihydrogen phosphate ion
Hexaaquairon(III) ion	$Fe(H_2O)_6^{3+}$	6.3×10^{-3}	$Fe(H_2O)_5OH^{2+}$	1.6×10^{-12}	pentaaquahydroxoiron(III) ion
Hydrofluoric acid	HF	7.2×10^{-4}	F^-	1.4×10^{-11}	fluoride ion
Nitrous acid	HNO_2	4.5×10^{-4}	NO_2^-	2.2×10^{-11}	nitrite ion
Formic acid	HCO_2H	1.8×10^{-4}	HCO_2^-	5.6×10^{-11}	formate ion
Benzoic acid	$C_6H_5CO_2H$	6.3×10^{-5}	$C_6H_5CO_2^-$	1.6×10^{-10}	benzoate ion
Acetic acid	CH_3CO_2H	1.8×10^{-5}	$CH_3CO_2^-$	5.6×10^{-10}	acetate ion
Propanoic acid	$CH_3CH_2CO_2H$	1.3×10^{-5}	$CH_3CH_2CO_2^-$	7.7×10^{-10}	propanoate ion
Hexaaquaaluminum ion	$Al(H_2O)_6^{3+}$	7.9×10^{-6}	$Al(H_2O)_5OH^{2+}$	1.3×10^{-9}	pentaaquahydroxoaluminum ion
Carbonic acid	H_2CO_3	4.2×10^{-7}	HCO_3^-	2.4×10^{-8}	hydrogen carbonate ion
Hexaaquacopper(II) ion	$Cu(H_2O)_6^{2+}$	1.6×10^{-7}	$Cu(H_2O)_5OH^+$	6.25×10^{-8}	pentaaquahydroxocopper(II) ion
Hydrogen sulfide	H_2S	1×10^{-7}	HS^-	1×10^{-7}	hydrogen sulfide ion
Dihydrogen phosphate ion	$H_2PO_4^-$	6.2×10^{-8}	HPO_4^{2-}	1.6×10^{-7}	hydrogen phosphate ion
Hydrogen sulfite ion	HSO_3^-	6.2×10^{-8}	SO_3^{2-}	1.6×10^{-7}	sulfite ion
Hypochlorous acid	$HClO$	3.5×10^{-8}	ClO^-	2.9×10^{-7}	hypochlorite ion
Hexaaquairon(II) ion	$Fe(H_2O)_6^{2+}$	1.5×10^{-8}	$Fe(H_2O)_5OH^+$	6.7×10^{-7}	pentaaquahydroxoiron(II) ion
Hexaaquacobalt(II) ion	$Co(H_2O)_6^{2+}$	1.3×10^{-9}	$Co(H_2O)_5OH^+$	7.7×10^{-6}	pentaaquahydroxocobalt(II) ion
Boric acid	$B(OH)_3(H_2O)$	7.3×10^{-10}	$B(OH)_4^-$	1.4×10^{-5}	tetrahydroxoborate ion
Ammonium ion	NH_4^+	5.6×10^{-10}	NH_3	1.8×10^{-5}	ammonia
Hydrocyanic acid	HCN	4.0×10^{-10}	CN^-	2.5×10^{-5}	cyanide ion
Hexaaquairon(II) ion	$Fe(H_2O)_6^{2+}$	3.2×10^{-10}	$Fe(H_2O)_5OH^+$	3.1×10^{-5}	pentaaquahydroxoiron(II) ion
Hydrogen carbonate ion	HCO_3^-	4.8×10^{-11}	CO_3^{2-}	2.1×10^{-4}	carbonate ion
Hexaaquanickel(II) ion	$Ni(H_2O)_6^{2+}$	2.5×10^{-11}	$Ni(H_2O)_5OH^+$	4.0×10^{-4}	pentaaquahydroxonickel(II) ion
Hydrogen phosphate ion	HPO_4^{2-}	3.6×10^{-13}	PO_4^{3-}	2.8×10^{-2}	phosphate ion
Water	H_2O	1.0×10^{-14}	OH^-	1.0	hydroxide ion
Hydrogen sulfide ion*	HS^-	1×10^{-14}	S^{2-}	1×10^{1}	sulfide ion
Ethanol	C_2H_5OH	very small	$C_2H_5O^-$	large	ethoxide ion
Ammonia	NH_3	very small	NH_2^-	large	amide ion
Hydrogen	H_2	very small	H^-	large	hydride ion

*The values of K_a for HS^- and K_b for S^{2-} are estimates.

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Aqueous solutions of salts

Table 17.4 Acid and Base Properties of Some Ions in Aqueous Solution

	Neutral		Basic			Acidic
Anions	Cl^- Br^- I^-	NO_3^- ClO_4^-	$CH_3CO_2^-$ HCO_2^- CO_3^{2-} S^{2-} F^-	CN^- PO_4^{3-} HCO_3^- HS^- NO_2^-	SO_4^{2-} HPO_4^{2-} SO_3^{2-} OCl^-	HSO_4^- $H_2PO_4^-$ HSO_3^-
Cations	Li^+ Na^+ K^+	Ca^{2+} Ba^{2+}	$[Al(H_2O)_5(OH)]^{2+}$ (for example)			$[Al(H_2O)_6]^{3+}$ and hydrated transition metal cations (such as $[Fe(H_2O)_6]^{3+}$) NH_4^+

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Predicting Effects of Salts on pH

Will dissolving the following salts increase the pH (↑), decrease the pH (↓), or leave it unchanged (↔)?

	1	2	3
KBr (*s*) → K^+(*aq*) + Br^-(*aq*)	~~↑~~	~~↓~~	↔
NH_4NO_3 (*s*) → NH_4^+(*aq*) + NO_3^- (*aq*)	~~↑~~	↓	~~↔~~
$AlCl_3$ (*s*) → Al^{3+}(*aq*) + $3Cl^-$(*aq*)	~~↑~~	↓	~~↔~~
Na_2HPO_4 (*s*) → $2Na^+$(*aq*) + HPO_4^{2-}(*aq*)	↑	~~↓~~	~~↔~~

Aqueous solutions of salts

Cation	Anion	pH
Strong base	Strong acid	=7
Strong base	Weak acid	>7
Weak base	Strong acid	<7
Weak base	Weak acid	depends on the K_a and K_b

if $K_a > K_b \rightarrow <7$
if $K_a < K_b \rightarrow >7$

The strongest rule