

Acid-Base Equilibria

Objective: The student will be able to (1) describe the Three Models of Acid-Base Theory, (2) classify strong and weak acids and bases, (3) discuss the interrelationship between pH, pOH, K_w , $[\text{H}_3\text{O}^+]$, and $[\text{OH}^-]$

Homework: Begin Acid-Base Problem Set #1

Warm - Up:

Write the formulas for the following complexes:

1. dioxosulfatomanganese (VI)
2. tin(IV) carbonylcarbonatodiiodoaluminate (III)

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Warm - Up Answers

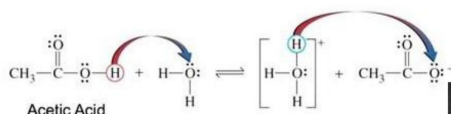
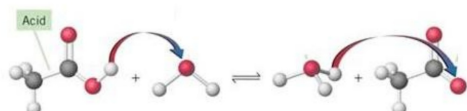


Remember from the first day of class that complexes are products of acid-base reactions. These products are known as adducts.



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Acid-Base Theory #1: Arrhenius Definition



Acids produce H_3O^+

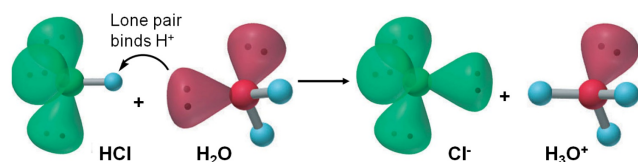
Bases produce OH^-

most restrictive of the definitions

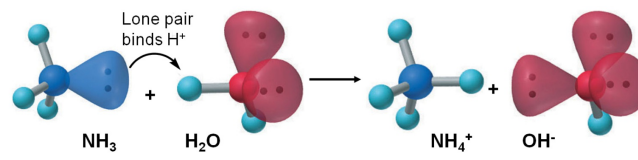


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Acid-Base Theory #2: Bronstead-Lowry Definition



HCl (acid, H^+ donor) + H₂O (base, H^+ acceptor) → Cl⁻ + H₃O⁺



NH₃ (base, H^+ acceptor) + H₂O (acid, H^+ donor) → NH₄⁺ + OH⁻

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Significance of the Bronsted-Lowry Definition

Acid-Base strength can be determined numerically by using tabular values. (Explain.)

ACID STRENGTH ↑		BASE STRENGTH ↓	
Strong	ACID HCl H ₂ SO ₄ HNO ₃ H ₃ O ⁺	Negligible	BASE Cl ⁻ HSO ₄ ⁻ NO ₃ ⁻ H ₂ O
	HSO ₄ ⁻ H ₂ SO ₃ H ₃ PO ₄ HF CH ₃ COOH H ₂ CO ₃ H ₂ S		SO ₄ ²⁻ HSO ₃ ⁻ H ₂ PO ₄ ⁻ F ⁻ CH ₃ COO ⁻ HCO ₃ ⁻ HS ⁻
Weak	HSO ₃ ⁻ H ₂ PO ₄ ⁻ HCN NH ₄ ⁺ HCO ₃ ⁻ HPO ₄ ²⁻ H ₂ O	Weak	SO ₃ ²⁻ HPO ₄ ²⁻ CN ⁻ NH ₃ CO ₃ ²⁻ PO ₄ ³⁻ OH ⁻
Negligible	HS ⁻ OH ⁻	Strong	S ²⁻ O ²⁻

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Problem

What is the conjugate acid when aqueous solutions of ammonia and hydrofluoric acid are mixed?

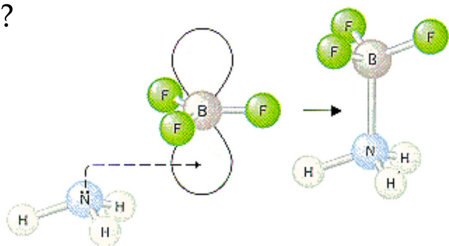
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Lewis Definition (G.N. Lewis)

Discusses the transfer of electrons

Problem

When BF₃ and NH₃ react, which is the Lewis acid?



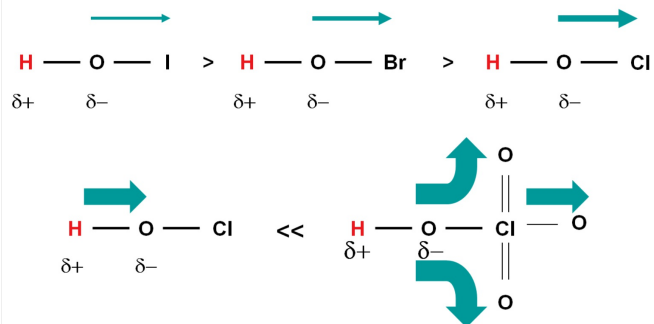
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Relative Strength of Acids and Bases

	Strong	Weak
Acids	hydrohalic hydrohalic oxoacids	hydrohalic sans H-O oxoacids carboxylic acids
	R-OH and R-O where R is a IA or IIA metal	Electron-rich nitrogen with lone pair
Bases		

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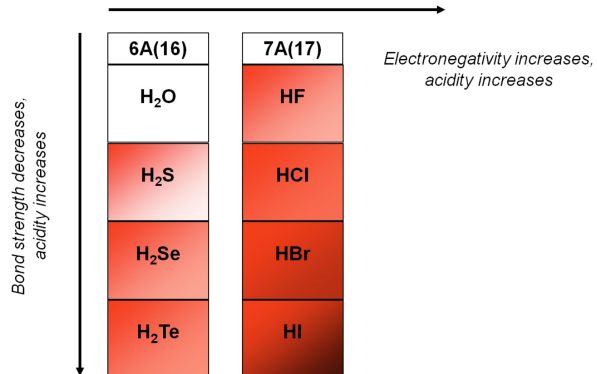
Derivation of the Strength of Oxoacids



Deals with electron withdrawing and electronegativity

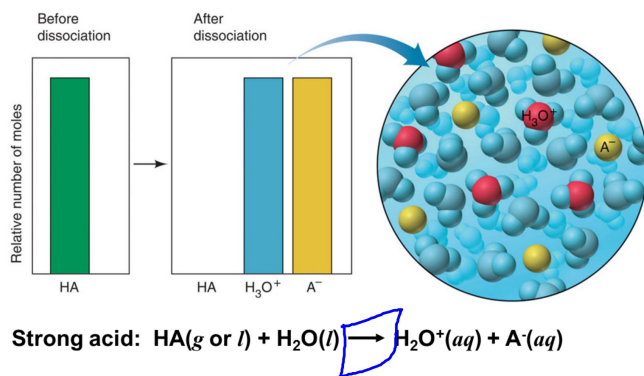
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Periodic Trends in Acid Strength



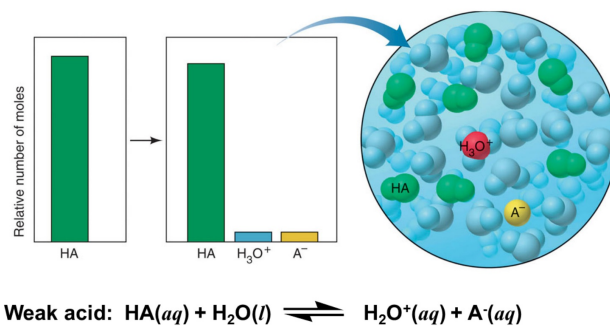
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The Extent of Dissociation for Strong Acids



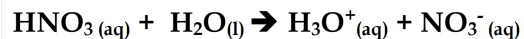
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The Extent of Dissociation for Weak Acids



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Acid Strength (K_a) and the Meaning of K



(derivation of K_a , strength / $[\text{H}_3\text{O}^+]$ / K_a relationship)

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General Characteristics of Acid-Base Solution Equilibrium

The acidity of a solution is based on the relationship between the $[\text{H}_3\text{O}^+]$ and the $[\text{OH}^-]$. When:

$[\text{H}_3\text{O}^+] > [\text{OH}^-]$	acidic
$[\text{H}_3\text{O}^+] = [\text{OH}^-]$	neutral
$[\text{H}_3\text{O}^+] < [\text{OH}^-]$	basic

What is K_w ?

Final Point: Rxn proceeds in greater extent in the direction of $\text{SA} + \text{SB} \rightarrow \text{WA} + \text{WB}$
(stronger) (weaker)

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Example: Extent of a Reaction

Consider the following system:

hydrofluoric acid is mixed with water

What is the extent of the reaction? (i.e. Which side of the reaction will be favored, products or reactants?)

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Practice

Consider these systems in equilibrium, individually:

(a) the dihydrogen phosphate ion is mixed with aqueous ammonia

(b) the bisulfide ion is mixed with water

For each system, what is the extent of the reaction?

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**Reminders of Basic Acid-Base Equations
from Chemistry I**

Remember $\text{H}^+ = \text{H}_3\text{O}^+$

$$\text{pH} = -\log([\text{H}^+]) \quad \text{or} \quad \text{pH} = -\log(\text{H}_3\text{O}^+)$$

$$\text{pOH} = -\log(\text{OH}^-)$$

$$K_w = [\text{H}^+][\text{OH}^-] \quad \text{pH} + \text{pOH} = 14$$

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Problem:

pH of a strong monoprotic acid or monobasic base

What is the pH of a 0.0023 M solution of nitric acid?

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When 0.556 grams of KOH are dissolved in enough water to make 2.00 liters of solution, what is the pH and the pOH?

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Problem:

pH of a strong dibasic base

When 2.6×10^{-3} moles of barium hydroxide are dissolved in enough water to make 25.0 liters of solution, what is the pOH, the pH and the $[\text{H}_3\text{O}^+]$?

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Phenylacetic acid ($\text{C}_6\text{H}_5\text{CH}_2\text{COOH}$, or HPAC) builds up in the blood of persons with phenylketonuria, an inherited disorder that, if left untreated causes mental retardation and death. A study of the acid shows that the pH of a 0.12 M HPAC solution is 2.62. What is the K_a of phenylacetic acid?

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Propanoic acid ($\text{CH}_3\text{CH}_2\text{COOH}$, HPr) is a carboxylic acid whose salts are used to retard growth in foods. What is the $[\text{H}_3\text{O}^+]$ of 0.10 M HPr? ($K_a = 1.3 \times 10^{-5}$)

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Ascorbic acid ($\text{H}_2\text{C}_6\text{H}_6\text{O}_6$, or HAsc), known as Vitamin C, is a diprotic acid ($K_{a,1} = 1.0 \times 10^{-5}$ and $K_{a,2} = 5 \times 10^{-12}$) found in citrus fruit. Calculate the $[\text{HAsc}^-]$, $[\text{Asc}^{2-}]$, and the pH of 0.050 M H_2Asc .

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Practice: Complications with sulfuric acid

What is the pH of a 0.122 M solution of sulfuric acid? (Look at the K_a values.)

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Weak Base Problems

(examples of weak bases, derivation of K_b constant)

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Sodium acetate (CH_3COONa , or NaAc) is used in textile dyeing. What is the pH of 0.25 M NaAc at 25°C ? K_a of acetic acid is 1.8×10^{-5} .

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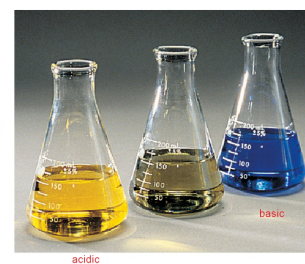
Sodium hypochlorite is the active ingredient in household laundry bleach. What is the pH of 0.20 M NaClO? ($K_a = 2.9 \times 10^{-8}$)

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Indicators

Weak organic acid (HIn) whose color is different from the color of its conjugate base (In^-).

Merits of diprotic indicator (H_2In).



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Henderson-Hasselbalch Equation

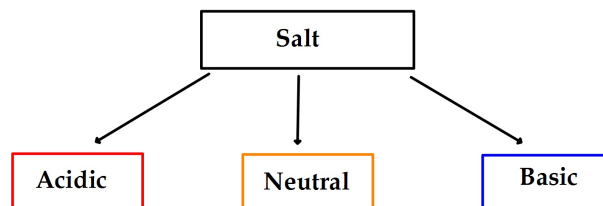
$$\text{pH} = \text{p}K_a + \log\left(\frac{[A^-]}{[HA]}\right)$$

This relationship allows the solving directly for pH instead of having to calculate $[\text{H}_3\text{O}^+]$.

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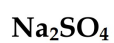
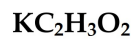
Salt Hydrolysis

The literal meaning of hydrolysis is the splitting of water (lysis = splitting, hydro = water). It is the opposite of a neutralization reaction.



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Salt Hydrolysis Examples



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