

Chapter 10 Acids and Bases

Most fundamental thing to remember
about this chapter: Acids and Bases
are opposites.

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Acids- the Arrhenius definition

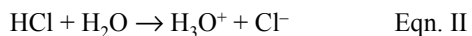
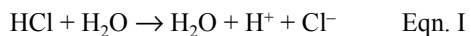
Arrhenius acid- substance that *dissociates* in
water to yield hydrogen ions (protons- H⁺)

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Acids Dissociate in Solution

Dissociate- acids and bases break apart into
ions when placed in water.

Previously: $\text{CaCl}_2 \rightarrow \text{Ca}^{2+} + 2 \text{Cl}^-$



Eqn I and Eqn II mean the same thing

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A Little More Complicated Dissociation

$$\begin{array}{c}
 \text{H} \quad \text{O} \\
 | \quad // \\
 \text{H}-\text{C}-\text{C}-\text{O}-\text{H} \\
 | \quad | \\
 \text{H} \quad \text{H}
 \end{array}
 + \text{H}_2\text{O} \rightleftharpoons \text{H}_3\text{O}^{\oplus} + \text{CH}_3\text{COO}^{\ominus}$$

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Properties of Acids

	<u>Acid</u>
Formula	HX
Taste	Sour
Touch	-----
Litmus	Blue → Red

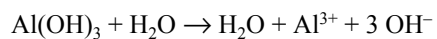
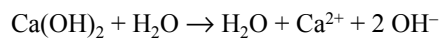
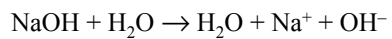
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Bases - the Arrhenius Definition

Arrhenius base- substance that dissociates in water to yield hydroxide ions (OH⁻)

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Bases Dissociate in Solution



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Properties of Bases

	<u>Base</u>
Formula	XOH
Taste	Bitter
Touch	Slippery
Litmus	Red → Blue

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Demonstration

Ammonia (NH₃) Turns Litmus Paper Blue

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Bronsted-Lowry Acids and Bases

Bronsted-Lowry acid- a proton donor

Bronsted-Lowry base- a proton acceptor

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Nomenclature of Bases and Acids

Bases

- X OH Element hydroxide
- NH₃ Ammonia

Acids

- no oxygen hydro + Element root + ic acid
- contains oxygen
 - identify polyatomic ion
 - change -ate to -ic or -ite to -ous
 - add acid

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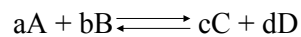
Sample Test Questions

Give the name or formula of the following acids and bases

- ammonia
- Al(OH)₃
- carbonic acid
- HNO₃

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Equilibrium Constant, Keq



$$K_{eq} = \frac{[\text{Products}]}{[\text{Reactants}]} = \frac{[C]^c[D]^d}{[A]^a[B]^b}$$

Keq big, \rightarrow

Keq small, \leftarrow

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Acid Ionization Constant, Ka



$$K_{eq} = \frac{[\text{H}_3\text{O}^+][\text{CH}_3\text{COO}^-]}{[\text{CH}_3\text{COOH}][\text{H}_2\text{O}]}$$

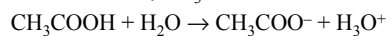
$$K_{eq}[\text{H}_2\text{O}] = \frac{[\text{H}_3\text{O}^+][\text{CH}_3\text{COO}^-]}{[\text{CH}_3\text{COOH}]} = K_a$$

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Strong Acids/Weak Acids

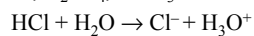
How strong an acid is depends on how much it dissociates.

Weak acid- acetic acid, CH_3COOH



$$K_a = 1.82 \times 10^{-5} \text{ (small)}$$

Strong acid- HCl , H_2SO_4 , HNO_3



$$K_a = \text{infinity (big)}$$

The K_a is a constant which you would be given

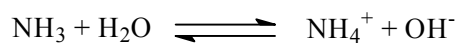
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Sample Test Questions

- The K_a for citric acid is 8.7×10^{-4} . Is citric acid a strong acid or a weak acid?
- The K_a for HNO_3 is infinity. Is HNO_3 a strong acid or a weak acid?

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Base Ionization Constant, K_b



$$K_{\text{eq}} = \frac{[\text{NH}_4^+][\text{OH}^-]}{[\text{NH}_3][\text{H}_2\text{O}]}$$

$$K_{\text{eq}}[\text{H}_2\text{O}] = \frac{[\text{NH}_4^+][\text{OH}^-]}{[\text{NH}_3]} = K_b$$

The K_b is a constant which you would be given

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Sample Test Questions

- The K_b for H_2O is 1.0×10^{-7} . Is H_2O a strong base or a weak base?

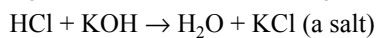
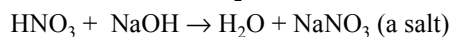
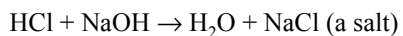
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Reactions of Acids

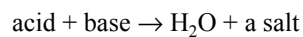
1. Neutralization reactions.

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All Neutralization Reactions are Similar



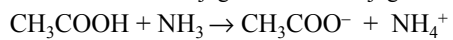
General Equation:



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Conjugate Acid/Conjugate Base

Acid + Base \rightarrow Conjugate Base + Conjugate Acid



Conjugate Acid- the acid that is formed when a base accepts a proton.

Conjugate Base- the base that is formed when an acid donates a proton.

conjugate acid-base pairs differ only by a H^+

If acid is strong, conjugate base is weak

If base is strong, conjugate acid is weak

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Acid-Base Titrations

- Performed in lab
 - Equation to use $(V_a)(N_a)=(V_b)(N_b)$
1. How many mL of 0.109 M HCl would be required to neutralize 25.00 mL of 0.2001 M NaOH?
 2. 25.00 mL of HCl of an unknown strength required 7.69 mL of 0.1956 N KOH to get to the equivalence point. What concentration is the HCl?

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Reactions of Acids

1. Neutralization reactions.
2. Reaction with metals
hydrogen gas produced: e.g.,
 $2 \text{HCl} + \text{Zn} \rightarrow \text{H}_2 + \text{ZnCl}_2$

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Reactions of Acids

3. Reaction with metal carbonates and bicarbonates
CO₂ gas produced: e.g.,
 $\text{NaHCO}_3 + \text{HCl} \rightarrow \text{NaCl} + \text{H}_2\text{CO}_3$
 $\text{H}_2\text{CO}_3 \rightarrow \text{H}_2\text{O} + \text{CO}_2$

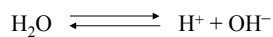
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Reactions of Acids

1. Neutralization reactions.
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hydrogen gas produced: e.g.,
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3. Reaction with metal carbonates and bicarbonates
 CO_2 produced: e.g.,
 $\text{NaHCO}_3 + \text{HCl} \rightarrow \text{NaCl} + \text{H}_2\text{CO}_3$
 $\text{H}_2\text{CO}_3 \rightarrow \text{H}_2\text{O} + \text{CO}_2$
4. Reaction with ammonia: ammonium produced

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Ionization of Water



$$K_{\text{eq}} = \frac{[\text{H}^+][\text{OH}^-]}{[\text{H}_2\text{O}]}$$

$$[\text{H}^+] = [\text{OH}^-] = 1.0 \times 10^{-7} \text{ M (experimentally)}$$

$$K_{\text{eq}} [\text{H}_2\text{O}] = [\text{H}^+][\text{OH}^-]$$

$$K_{\text{w}} = 1.0 \times 10^{-14}$$

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pH Scale

scale of 0-14

low pH (pH 0 - pH 6) is acidic

pH 7 is neutral

high pH (pH 8 - pH 14) is basic

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

Because log scale, a difference of 1 pH unit means there are $10\times$ as many protons.

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pH Math

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

$$\text{pOH} = -\log [\text{OH}^-]$$

$$[\text{H}_3\text{O}^+][\text{OH}^-] = 1.0 \times 10^{-14}$$

$$\text{pH} + \text{pOH} = 14$$

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Sample Test Questions

- What is the pH of a solution containing 1.0×10^{-6} M HCl?
- What is the pH of a solution containing 1.0×10^{-6} M NaOH?
- How many more protons are in a solution of pH 4.0 than one of pH 6.0?
- How many more protons are in a solution of pH 4.0 than one of pH 4.3?

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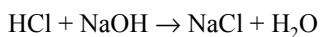
Sample Test Questions

- What is the $[\text{H}_3\text{O}^+]$ in blood at pH 7.40?
- What is the pH of a solution containing 0.365 g hydrochloric acid in 500.0 mL water?
- What is the pH of a solution containing 9.25 g sodium hydroxide in 250.0 mL water?

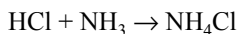
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pH of Salt Solutions

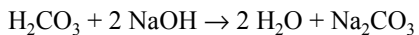
Acid + base \rightarrow water + salt



strong acid, strong base: neutral solutions.



Strong acid, weak base: acidic



Weak acid, strong base: basic

Weak acid, weak base: can't predict easily

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Buffers

Buffer- a compound that does not allow the pH to change even if acid or base is added to the system.

Must have a weak acid and its salt. Good buffers are often *amphiprotic* compounds.

Amphiprotic compound- a compound that can act as a proton donor or as a proton acceptor.

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Buffers

Why do buffers have to be a weak acid and salt of weak acid?

Compounds are good buffers at $\text{pH} = \pm 0.5 \text{ pKa}$ (because within this range they exist as weak acid and salt of weak acid).

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Sample Test Questions

The pKa of oxalic acid is 4.3. In what pH range would oxalic acid be a good buffer?

The K_{a1} of H_3PO_4 is 7.107×10^{-3} . What is the pKa₁ of H_3PO_4 ?

The K_{a2} of citric acid is 1.73×10^{-5} . In what pH range would citric acid be a good buffer?

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pH with Buffers: the Henderson-Hasselbalch Equation

$$pH = pKa + \log \frac{[\text{salt}]}{[\text{acid}]}$$

$$pH = pKa + \log \frac{[A^-]}{[HA]}$$

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Sample Test Questions

If I mix 50.0 mL of 1.6 M NaH_2PO_4 with 25.0 mL of 1.6 M Na_2HPO_4 , what would the pH of the mixture be? The pKa is 7.21.

$$\begin{aligned} pH &= pKa + \log \frac{[A^-]}{[HA]} \\ &= 7.21 + \log \frac{[0.53 \text{ M}]}{[1.07 \text{ M}]} \\ &= 7.21 + \log 0.5 \\ &= 7.21 + (-0.30) \\ pH &= 6.91 \end{aligned}$$

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Sample Test Questions

If I mix 10.0 mL of 1.0 M CH_3COOH with 10.0 mL of 1.0 M CH_3COO^- , what would the pH of the mixture be? The K_a of CH_3COOH is 1.8×10^{-5} .

If I mix 20.0 mL of the above buffer with with 1.2 mL 1.0 M NaOH , what would the pH of the mixture be?

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Buffers in Lab

Solution 6: 10 mL 1 M NH_4OH , 10 mL 1 M NH_4^+
Solution 6

$$\begin{aligned} \text{pH} &= \text{p}K_a + \log \frac{[\text{A}^-]}{[\text{HA}]} \\ &= 9.23 + \log \frac{\left[\frac{(10 \text{ mL } \text{NH}_4\text{OH})(1 \text{ M})}{20 \text{ mL}} \right]}{\left[\frac{(10 \text{ mL } \text{NH}_4\text{Cl})(1 \text{ M})}{20 \text{ mL}} \right]} \\ &= 9.23 + \log 1 \\ &= 9.23 + (0) \\ \text{pH} &= 9.23 \end{aligned}$$

Solution 7

$$\begin{aligned} \text{pH} &= \text{p}K_a + \log \frac{[\text{A}^-]}{[\text{HA}]} \\ &= 9.23 + \log \frac{[5]}{[20]} \\ &= 9.23 + \log 0.25 \\ &= 9.23 + (-0.60) \\ \text{pH} &= 8.63 \end{aligned}$$

Solution 7: 5 mL 1 M NH_4OH , 20 mL 1 M NH_4^+

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Summary of Acids and Bases

	<u>Acid</u>	<u>Base</u>
Arrhenius dfn	ionizes to H^+	ionizes to OH^-
B-L dfn	proton donor	proton acceptor
Formula	HX	XOH
Taste	Sour	Bitter
Touch	-----	Slippery
Litmus	Blue \rightarrow Red	Red \rightarrow Blue
pH	<7	>7
Reactions	Neutralizes Base	Neutralizes Acid
