

## Acids and Bases

### Chapter 15

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## Acids

Have a sour taste. Vinegar owes its taste to acetic acid. Citrus fruits contain citric acid.

React with certain metals to produce hydrogen gas.

React with carbonates and bicarbonates to produce carbon dioxide gas

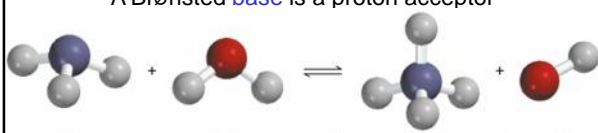
## Bases

Have a bitter taste.

Feel slippery. Many soaps contain bases.

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A Brønsted **acid** is a proton donor  
A Brønsted **base** is a proton acceptor



$$\text{NH}_3(aq) + \text{H}_2\text{O}(l) \rightleftharpoons \text{NH}_4^+(aq) + \text{OH}^-(aq)$$

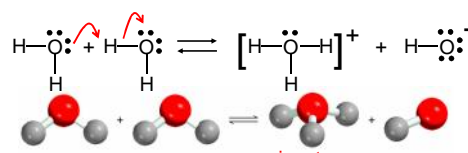
base	acid	$\rightleftharpoons$	acid		base
base	acid		conjugate acid		conjugate base

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### Acid-Base Properties of Water

$$\text{H}_2\text{O}(l) \rightleftharpoons \text{H}^+(aq) + \text{OH}^-(aq)$$

**autoionization** of water



$$\text{H}_2\text{O} + \text{H}_2\text{O} \rightleftharpoons \text{H}_3\text{O}^+ + \text{OH}^-$$

base	acid		conjugate acid		conjugate base
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### The Ion Product of Water

$$\text{H}_2\text{O}(l) \rightleftharpoons \text{H}^+(aq) + \text{OH}^-(aq) \quad K_c = \frac{[\text{H}^+][\text{OH}^-]}{[\text{H}_2\text{O}]} \quad [\text{H}_2\text{O}] = \text{constant}$$

$$K_c[\text{H}_2\text{O}] = K_w = [\text{H}^+][\text{OH}^-]$$

The **ion-product constant** ( $K_w$ ) is the product of the molar concentrations of  $\text{H}^+$  and  $\text{OH}^-$  ions **at a particular temperature**.

At 25°C $K_w = [\text{H}^+][\text{OH}^-] = 1.0 \times 10^{-14}$	<b>Solution Is</b>
$[\text{H}^+] = [\text{OH}^-]$	neutral
$[\text{H}^+] > [\text{OH}^-]$	<b>acidic</b>
$[\text{H}^+] < [\text{OH}^-]$	<b>basic</b>

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What is the concentration of  $\text{OH}^-$  ions in a HCl solution whose hydrogen ion concentration is 1.3 M?

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

$$[\text{H}^+] = 1.3 \text{ M}$$

$$[\text{OH}^-] = \frac{K_w}{[\text{H}^+]} = \frac{1.0 \times 10^{-14}}{1.3} = 7.7 \times 10^{-15} \text{ M}$$

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## pH – A Measure of Acidity

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

**Solution Is**

	At 25°C		
neutral	$[\text{H}^+] = [\text{OH}^-]$	$[\text{H}^+] = 1 \times 10^{-7}$	pH = 7
acidic	$[\text{H}^+] > [\text{OH}^-]$	$[\text{H}^+] > 1 \times 10^{-7}$	pH < 7
basic	$[\text{H}^+] < [\text{OH}^-]$	$[\text{H}^+] < 1 \times 10^{-7}$	pH > 7

$$\text{pH} \uparrow \quad [\text{H}^+] \downarrow$$

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TABLE 15.1

The pHs of Some Common Fluids

Sample	pH Value
Gastric juice in the stomach	1.0–2.0
Lemon juice	2.4
Vinegar	3.0
Grapefruit juice	3.2
Orange juice	3.5
Lime	4.8–7.5
Water exposed to air*	5.5
Saliva	6.4–6.9
Milk	6.5
Pure water	7.0
Blood	7.35–7.45
Tears	7.4
Milk of magnesia	10.6
Household ammonia	11.5

\*Water exposed to air for a long period of time absorbs atmospheric  $\text{CO}_2$  to form carbonic acid,  $\text{H}_2\text{CO}_3$ .

Other important relationships

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

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

$$-\log [\text{H}^+] - \log [\text{OH}^-] = 14.00$$

$$\text{pH} + \text{pOH} = 14.00$$



pH Meter

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The pH of rainwater collected in a certain region of the northeastern United States on a particular day was 4.82. What is the  $\text{H}^+$  ion concentration of the rainwater?

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

$$[\text{H}^+] = 10^{-\text{pH}} = 10^{-4.82} = 1.5 \times 10^{-5} \text{ M}$$

The  $\text{OH}^-$  ion concentration of a blood sample is  $2.5 \times 10^{-7} \text{ M}$ . What is the pH of the blood?

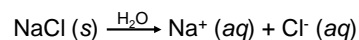
$$\text{pH} + \text{pOH} = 14.00$$

$$\text{pOH} = -\log [\text{OH}^-] = -\log (2.5 \times 10^{-7}) = 6.60$$

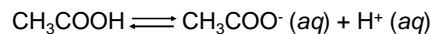
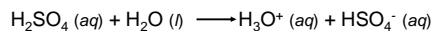
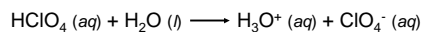
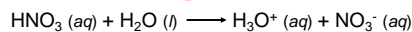
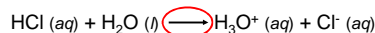
$$\text{pH} = 14.00 - \text{pOH} = 14.00 - 6.60 = 7.40$$

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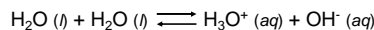
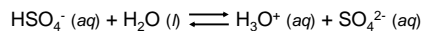
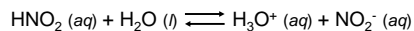
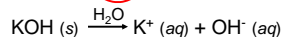
Strong Electrolyte – 100% dissociation



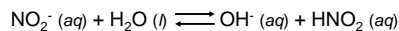
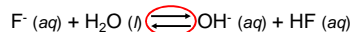
Weak Electrolyte – not completely dissociated

**Strong Acids** are strong electrolytes

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**Weak Acids** are weak electrolytes**Strong Bases** are strong electrolytes

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**Weak Bases** are weak electrolytes**Conjugate acid-base pairs:**

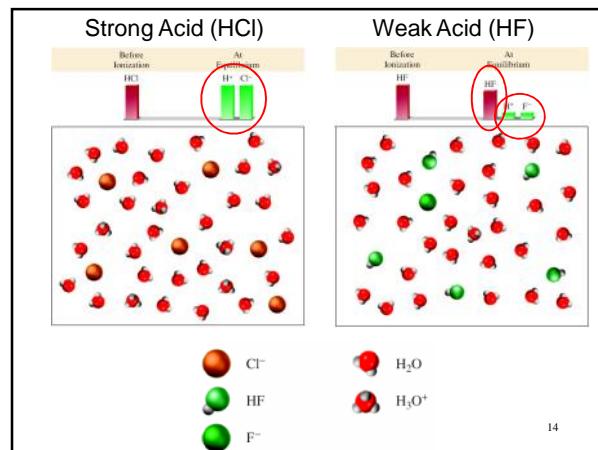
- The conjugate base of a strong acid has no measurable strength.
- $\text{H}_3\text{O}^+$  is the strongest acid that can exist in aqueous solution.
- The  $\text{OH}^-$  ion is the strongest base that can exist in aqueous solution.

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TABLE 15.2 Relative Strengths of Conjugate Acid-Base Pairs

Acid	Conjugate Base
HClO <sub>4</sub> (perchloric acid)	ClO <sub>4</sub> <sup>-</sup> (perchlorate ion)
HI (hydroiodic acid)	I <sup>-</sup> (iodide ion)
HBr (hydrobromic acid)	Br <sup>-</sup> (bromide ion)
HCl (hydrochloric acid)	Cl <sup>-</sup> (chloride ion)
H <sub>2</sub> SO <sub>4</sub> (sulfuric acid)	HSO <sub>4</sub> <sup>-</sup> (hydrogen sulfate ion)
HNO <sub>3</sub> (nitric acid)	NO <sub>3</sub> <sup>-</sup> (nitrate ion)
H <sub>2</sub> O <sup>+</sup> (hydronium ion)	H <sub>2</sub> O (water)
HSO <sub>4</sub> <sup>-</sup> (hydrogen sulfate ion)	SO <sub>4</sub> <sup>2-</sup> (sulfate ion)
HF (hydrofluoric acid)	F <sup>-</sup> (fluoride ion)
HNO <sub>2</sub> (nitrous acid)	NO <sub>2</sub> <sup>-</sup> (nitrite ion)
HCOOH (formic acid)	HCOO <sup>-</sup> (formate ion)
CH <sub>3</sub> COOH (acetic acid)	CH <sub>3</sub> COO <sup>-</sup> (acetate ion)
NH <sub>4</sub> <sup>+</sup> (ammonium ion)	NH <sub>3</sub> (ammonia)
HCN (hydrocyanic acid)	CN <sup>-</sup> (cyanide ion)
H <sub>2</sub> O (water)	OH <sup>-</sup> (hydroxide ion)
NH <sub>3</sub> (ammonia)	NH <sub>2</sub> <sup>-</sup> (amide ion)

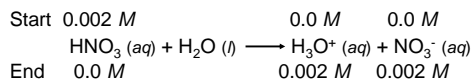
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What is the pH of a  $2 \times 10^{-3} M$  HNO<sub>3</sub> solution?

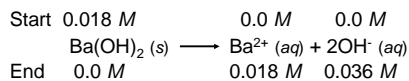
HNO<sub>3</sub> is a strong acid – 100% dissociation.



$$\text{pH} = -\log [\text{H}^+] = -\log [\text{H}_3\text{O}^+] = -\log(0.002) = 2.7$$

What is the pH of a  $1.8 \times 10^{-2} M$  Ba(OH)<sub>2</sub> solution?

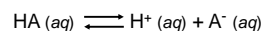
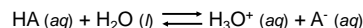
Ba(OH)<sub>2</sub> is a strong base – 100% dissociation.



$$\text{pH} = 14.00 - \text{pOH} = 14.00 + \log(0.036) = 12.6$$

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Weak Acids (HA) and Acid Ionization Constants



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

$K_a$  is the **acid ionization constant**



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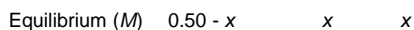
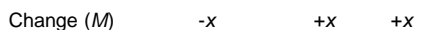
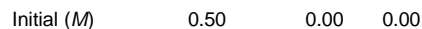
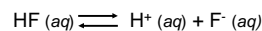
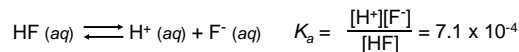
TABLE 15.3 Ionization Constants of Some Weak Acids and Their Conjugate Bases at 25°C

Name of Acid	Formula	Structure	$K_a$	Conjugate Base	$K_b$
Hydrofluoric acid	HF	H—F	$7.1 \times 10^{-4}$	F <sup>-</sup>	$1.4 \times 10^{-11}$
Nitrous acid	HNO <sub>2</sub>	O=N—O—H	$4.5 \times 10^{-4}$	NO <sub>2</sub> <sup>-</sup>	$2.2 \times 10^{-11}$
Acetylsalicylic acid (aspirin)	C <sub>9</sub> H <sub>7</sub> O <sub>4</sub>		$3.6 \times 10^{-4}$	C <sub>9</sub> H <sub>7</sub> O <sub>4</sub> <sup>-</sup>	$3.3 \times 10^{-11}$
Formic acid	HCOOH		$1.7 \times 10^{-4}$	HCOO <sup>-</sup>	$5.9 \times 10^{-11}$
Ascorbic acid*	C <sub>6</sub> H <sub>8</sub> O <sub>6</sub>		$8.0 \times 10^{-5}$	C <sub>6</sub> H <sub>7</sub> O <sub>6</sub> <sup>-</sup>	$1.3 \times 10^{-11}$
Rothmic acid	C <sub>6</sub> H <sub>5</sub> COOH		$6.5 \times 10^{-5}$	C <sub>6</sub> H <sub>5</sub> COO <sup>-</sup>	$1.5 \times 10^{-11}$
Acetic acid	CH <sub>3</sub> COOH		$1.8 \times 10^{-5}$	CH <sub>3</sub> COO <sup>-</sup>	$5.6 \times 10^{-11}$
Cyanoacetic acid	HCN	H—C≡N	$4.9 \times 10^{-10}$	CN <sup>-</sup>	$2.0 \times 10^{-5}$
Formal	C <sub>2</sub> H <sub>2</sub> O <sub>2</sub>		$1.3 \times 10^{-10}$	C <sub>2</sub> H <sub>2</sub> O <sub>2</sub> <sup>-</sup>	$7.7 \times 10^{-5}$

\*pK<sub>a</sub> = 4.10 and 11.6 for the two ionizable protons of ascorbic acid. The two ionizable protons are shown in red in the structure.

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What is the pH of a 0.5 M HF solution (at 25°C)?



$$K_a = \frac{x^2}{0.50 - x} = 7.1 \times 10^{-4} \quad K_a \ll 1 \quad 0.50 - x \approx 0.50$$

$$K_a \approx \frac{x^2}{0.50} = 7.1 \times 10^{-4} \quad x^2 = 3.55 \times 10^{-4} \quad x = 0.019 M$$

$$[\text{H}^+] = [\text{F}^-] = 0.019 M \quad \text{pH} = -\log [\text{H}^+] = 1.72$$

$$[\text{HF}] = 0.50 - x = 0.48 M$$

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When can I use the approximation?

$$K_a \ll 1 \quad 0.50 - x \approx 0.50$$

When  $x$  is less than 5% of the value from which it is subtracted.

$$x = 0.019 \quad \frac{0.019 M}{0.50 M} \times 100\% = 3.8\% \quad \begin{array}{l} \text{Less than 5\%} \\ \text{Approximation ok.} \end{array}$$

What is the pH of a 0.05 M HF solution (at 25°C)?

$$K_a \approx \frac{x^2}{0.05} = 7.1 \times 10^{-4} \quad x = 0.006 M$$

$$\frac{0.006 M}{0.05 M} \times 100\% = 12\% \quad \begin{array}{l} \text{More than 5\%} \\ \text{Approximation not ok.} \end{array}$$

Must solve for  $x$  exactly using quadratic equation or method of successive approximations.

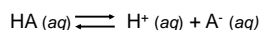
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### Solving weak acid ionization problems:

- Identify the major species that can affect the pH.
  - In most cases, you can ignore the autoionization of water.
  - Ignore  $[\text{OH}^-]$  because it is determined by  $[\text{H}^+]$ .
- Use ICE to express the equilibrium concentrations in terms of single unknown  $x$ .
- Write  $K_a$  in terms of equilibrium concentrations. Solve for  $x$  by the approximation method. If approximation is not valid, solve for  $x$  exactly.
- Calculate concentrations of all species and/or pH of the solution.

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What is the pH of a 0.122 M monoprotic acid whose  $K_a$  is  $5.7 \times 10^{-4}$ ?



Initial (M)	0.122	0.00	0.00
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Change (M)	-x	+x	+x
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Equilibrium (M)	0.122 - x	x	x
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$$K_a = \frac{x^2}{0.122 - x} = 5.7 \times 10^{-4} \quad K_a \ll 1 \quad 0.122 - x \approx 0.122$$

$$K_a \approx \frac{x^2}{0.122} = 5.7 \times 10^{-4} \quad x^2 = 6.95 \times 10^{-5} \quad x = 0.0083 M$$

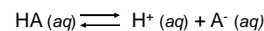
$$\frac{0.0083 M}{0.122 M} \times 100\% = 6.8\% \quad \begin{array}{l} \text{More than 5\%} \\ \text{Approximation not ok.} \end{array}$$

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$$K_a = \frac{x^2}{0.122 - x} = 5.7 \times 10^{-4} \quad x^2 + 0.00057x - 6.95 \times 10^{-5} = 0$$

$$ax^2 + bx + c = 0 \quad x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

$$x = 0.0081 \quad x = -0.0081$$



Initial (M)	0.122	0.00	0.00
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Change (M)	-x	+x	+x
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Equilibrium (M)	0.122 - x	x	x
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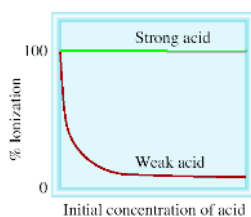
$$[\text{H}^+] = x = 0.0081 M \quad \text{pH} = -\log[\text{H}^+] = 2.09$$

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$$\text{percent ionization} = \frac{\text{ionized acid concentration at equilibrium}}{\text{initial concentration of acid}} \times 100\%$$

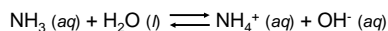
For a monoprotic acid HA

$$\text{Percent ionization} = \frac{[\text{H}^+]}{[\text{HA}]_0} \times 100\% \quad [\text{HA}]_0 = \text{initial concentration}$$



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### Weak Bases and Base Ionization Constants



$$K_b = \frac{[\text{NH}_4^+][\text{OH}^-]}{[\text{NH}_3]}$$

$K_b$  is the **base ionization constant**

$$K_b \uparrow \quad \text{weak base strength} \uparrow$$

Solve weak base problems like weak acids **except** solve for  $[\text{OH}^-]$  instead of  $[\text{H}^+]$ .

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**TABLE 15.4** Ionization Constants of Some Weak Bases and Their Conjugate Acids at 25°C

Name of Base	Formula	Structure	$K_b$	Conjugate Acid	$K_a$
Ethylamine	$C_2H_5NH_2$	<chem>CCN</chem>	$5.6 \times 10^{-4}$	$C_2H_5NH_3^+$	$1.8 \times 10^{-11}$
Methylamine	$CH_3NH_2$	<chem>CN</chem>	$4.4 \times 10^{-4}$	$CH_3NH_3^+$	$2.3 \times 10^{-11}$
Ammonia	$NH_3$	<chem>N</chem>	$1.8 \times 10^{-5}$	$NH_4^+$	$5.6 \times 10^{-10}$
Pyridine	$C_5H_5N$	<chem>c1ccncc1</chem>	$1.7 \times 10^{-7}$	$C_5H_5NH^+$	$5.9 \times 10^{-8}$
Acetone	$C_3H_6O$	<chem>CC(=O)C</chem>	$1.9 \times 10^{-17}$	$C_3H_7O^+$	$5.3 \times 10^{-18}$
Caffeine	$C_8H_{10}N_4O_2$	<chem>CN1C=NC2=C1C(=O)N(C(=O)N2C)C</chem>	$2.5 \times 10^{-14}$	$C_8H_{10}N_4O_2^+$	0.09
Urea	$(NH_2)_2CO$	<chem>NC(=O)N</chem>	$1.3 \times 10^{-14}$	$(NH_3CO)^+$	0.67

The hydrogen atoms are not shown on all structural models. In those of urea, the nitrogen is bonded to two hydrogen atoms.

### Ionization Constants of Conjugate Acid-Base Pairs

$$HA(aq) \rightleftharpoons H^+(aq) + A^-(aq) \quad K_a$$

$$A^-(aq) + H_2O(l) \rightleftharpoons OH^-(aq) + HA(aq) \quad K_b$$

$$H_2O(l) \rightleftharpoons H^+(aq) + OH^-(aq) \quad K_w$$

$K_a K_b = K_w$


Weak Acid and Its Conjugate Base

$$K_a = \frac{K_w}{K_b} \quad K_b = \frac{K_w}{K_a}$$

### Diprotic and Triprotic Acids

- May yield more than one hydrogen ion per molecule.
- Ionize in a stepwise manner; that is, they lose one proton at a time.
- An ionization constant expression can be written for each ionization stage.
- Consequently, two or more equilibrium constant expressions must often be used to calculate the concentrations of species in the acid solution.

$$H_2CO_3(aq) \rightleftharpoons H^+(aq) + HCO_3^-(aq) \quad K_{a1} = \frac{[H^+][HCO_3^-]}{[H_2CO_3]}$$

$$HCO_3^-(aq) \rightleftharpoons H^+(aq) + CO_3^{2-}(aq) \quad K_{a2} = \frac{[H^+][CO_3^{2-}]}{[HCO_3^-]}$$


**TABLE 15.5** Ionization Constants of Some Inorganic Acids and Polyprotic Acids at 25°C

Name of Acid	Formula	Structure	$K_{a1}$	Conjugate Base	$K_{a2}$
Sulfuric acid	$H_2SO_4$	<chem>OS(=O)(=O)O</chem>	$1.0 \times 10^{-1}$	$HSO_4^-$	$1.0 \times 10^{-2}$
Phosphoric acid	$H_3PO_4$	<chem>OP(=O)(O)O</chem>	$7.5 \times 10^{-3}$	$H_2PO_4^-$	$6.2 \times 10^{-8}$
Carbonic acid	$H_2CO_3$	<chem>OC(=O)O</chem>	$4.3 \times 10^{-7}$	$HCO_3^-$	$4.7 \times 10^{-11}$
Diphosphoric acid	$H_4P_2O_7$	<chem>OP(=O)(O)OP(=O)(O)O</chem>	$1.0 \times 10^{-1}$	$H_3P_2O_7^-$	$1.0 \times 10^{-2}$
Selenic acid	$H_2SeO_4$	<chem>OS(=O)(=O)O</chem>	$1.0 \times 10^{-1}$	$HSeO_4^-$	$1.0 \times 10^{-2}$
Phosphoric acid	$H_3PO_4$	<chem>OP(=O)(O)O</chem>	$7.5 \times 10^{-3}$	$H_2PO_4^-$	$6.2 \times 10^{-8}$
Phosphorous acid	$H_3PO_3$	<chem>OP(=O)O</chem>	$1.0 \times 10^{-1}$	$H_2PO_3^-$	$1.0 \times 10^{-2}$
Phosphoric acid	$H_3PO_4$	<chem>OP(=O)(O)O</chem>	$7.5 \times 10^{-3}$	$H_2PO_4^-$	$6.2 \times 10^{-8}$
Phosphorous acid	$H_3PO_3$	<chem>OP(=O)O</chem>	$1.0 \times 10^{-1}$	$H_2PO_3^-$	$1.0 \times 10^{-2}$
Phosphoric acid	$H_3PO_4$	<chem>OP(=O)(O)O</chem>	$7.5 \times 10^{-3}$	$H_2PO_4^-$	$6.2 \times 10^{-8}$
Phosphorous acid	$H_3PO_3$	<chem>OP(=O)O</chem>	$1.0 \times 10^{-1}$	$H_2PO_3^-$	$1.0 \times 10^{-2}$
Phosphoric acid	$H_3PO_4$	<chem>OP(=O)(O)O</chem>	$7.5 \times 10^{-3}$	$H_2PO_4^-$	$6.2 \times 10^{-8}$
Phosphorous acid	$H_3PO_3$	<chem>OP(=O)O</chem>	$1.0 \times 10^{-1}$	$H_2PO_3^-$	$1.0 \times 10^{-2}$

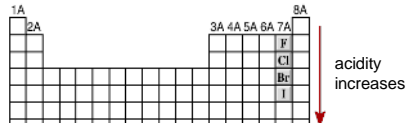
HA = hydrogen atom; H = hydrogen atom; O = oxygen atom; P = phosphorus atom; S = sulfur atom; Se = selenium atom.

### Molecular Structure and Acid Strength

$$H-X \longrightarrow H^+ + X^-$$

↑
↑  
 The stronger the bond      The weaker the acid

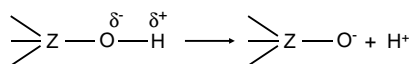
$HF \ll HCl < HBr < HI$



**TABLE 15.6** Bond Enthalpies for Hydrogen Halides and Acid Strengths for Hydrohalic Acids

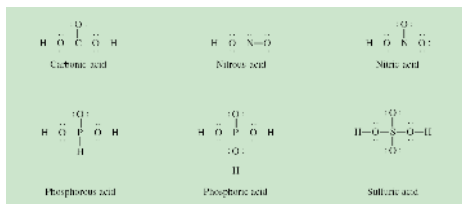
Bond	Bond Enthalpy (kJ/mol)	Acid Strength
H—F	568.2	weak
H—Cl	431.9	strong
H—Br	366.1	strong
H—I	298.3	strong

## Molecular Structure and Oxoacid Strength



The O-H bond will be more polar and easier to break if:

- Z is very electronegative or
- Z is in a high oxidation state



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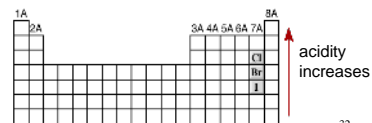
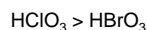
## Molecular Structure and Oxoacid Strength

1. Oxoacids having different central atoms (Z) that are from the same group and that have the same oxidation number.

Acid strength increases with increasing electronegativity of Z



Cl is more electronegative than Br

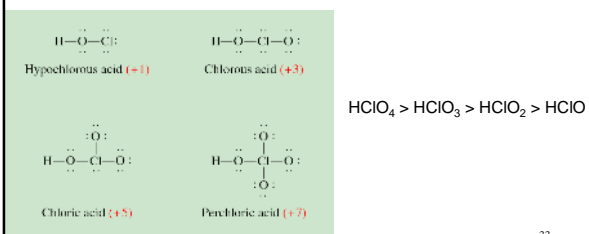


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## Molecular Structure and Acid Strength

2. Oxoacids having the same central atom (Z) but different numbers of attached groups.

Acid strength increases as the oxidation number of Z increases.

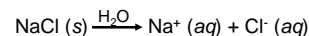


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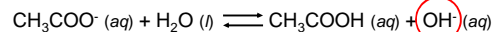
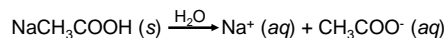
## Acid-Base Properties of Salts

**Neutral Solutions:**

Salts containing an alkali metal or alkaline earth metal ion (except  $\text{Be}^{2+}$ ) and the conjugate base of a strong acid (e.g.  $\text{Cl}^-$ ,  $\text{Br}^-$ , and  $\text{NO}_3^-$ ).

**Basic Solutions:**

Salts derived from a strong base and a weak acid.

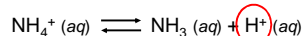
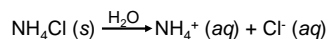


34

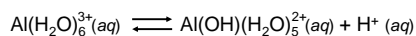
## Acid-Base Properties of Salts

**Acid Solutions:**

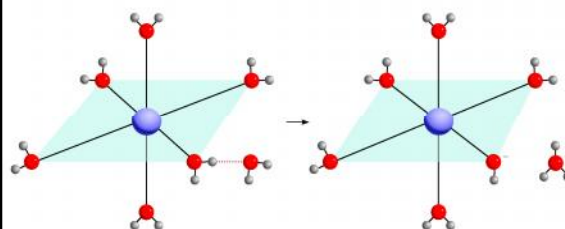
Salts derived from a strong acid and a weak base.



Salts with small, highly charged metal cations (e.g.  $\text{Al}^{3+}$ ,  $\text{Cr}^{3+}$ , and  $\text{Be}^{2+}$ ) and the conjugate base of a strong acid.



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Acid Hydrolysis of  $\text{Al}^{3+}$ 

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## Acid-Base Properties of Salts

### Solutions in which both the cation and the anion hydrolyze:

- $K_b$  for the anion  $>$   $K_a$  for the cation, solution will be basic
- $K_b$  for the anion  $<$   $K_a$  for the cation, solution will be acidic
- $K_b$  for the anion  $\approx$   $K_a$  for the cation, solution will be neutral

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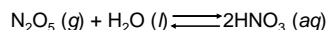
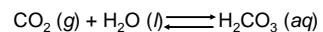
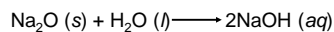
TABLE 16.7 Acid-Base Properties of Salts

Type of Salt	Examples	Ions That Undergo Hydrolysis	pH of Solution
Cation from strong base; anion from strong acid	$\text{NaCl}$ , $\text{KCl}$ , $\text{KNO}_3$ , $\text{RbCl}$ , $\text{BaCl}_2$	None	$\approx 7$
Cation from strong base; anion from weak acid	$\text{CH}_3\text{COONa}$ , $\text{KNO}_2$	Anion	$> 7$
Cation from weak base; anion from strong acid	$\text{NH}_4\text{Cl}$ , $\text{NH}_4\text{NO}_3$	Cation	$< 7$
Cation from weak base; anion from weak acid	$\text{NH}_4\text{NO}_2$ , $\text{CH}_3\text{COONH}_4$ , $\text{NH}_4\text{CN}$	Anion and cation	$< 7$ if $K_b < K_a$ $\approx 7$ if $K_b \approx K_a$ $> 7$ if $K_b > K_a$
Small, highly charged cation; anion from strong acid	$\text{AlCl}_3$ , $\text{Fe(NO}_3)_3$	Hydrated cation	$< 7$

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## Oxides of the Representative Elements In Their Highest Oxidation States

1A												13A		14A		15A		16A		17A		18A		
Li, Na, K, Rb, Cs, Fr												B, Al, Ga, In, Tl		C, Si, Ge, Sn, Pb		N, P, As, Sb, Bi		S, Se, Te, Po		H, F, Cl, Br, I, At		He, Ne, Ar, Kr, Xe, Rn		
Li <sub>2</sub> O	Na <sub>2</sub> O											B <sub>2</sub> O <sub>3</sub>	CO <sub>2</sub>	N <sub>2</sub> O <sub>5</sub>			OF <sub>2</sub>							
K <sub>2</sub> O	Rb <sub>2</sub> O											Al <sub>2</sub> O <sub>3</sub>	SiO <sub>2</sub>	P <sub>2</sub> O <sub>5</sub>			SO <sub>2</sub>	Cl <sub>2</sub> O <sub>7</sub>						
CaO	Strontium oxide											GeO <sub>2</sub>	SnO <sub>2</sub>	As <sub>2</sub> O <sub>5</sub>	Sb <sub>2</sub> O <sub>5</sub>	Bi <sub>2</sub> O <sub>3</sub>								
CaO	Strontium oxide											In <sub>2</sub> O <sub>3</sub>	SaO <sub>2</sub>	Sb <sub>2</sub> O <sub>3</sub>	TeO <sub>2</sub>	I <sub>2</sub> O <sub>5</sub>								
CaO	Strontium oxide											Tl <sub>2</sub> O <sub>3</sub>	PbO <sub>2</sub>	Bi <sub>2</sub> O <sub>3</sub>	PoO <sub>2</sub>	At <sub>2</sub> O <sub>3</sub>								



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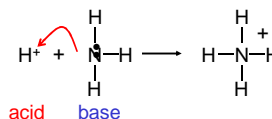
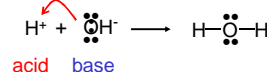
## Definition of An Acid

A **Arrhenius acid** is a substance that produces  $\text{H}^+$  ( $\text{H}_3\text{O}^+$ ) in water

A **Brønsted acid** is a proton donor

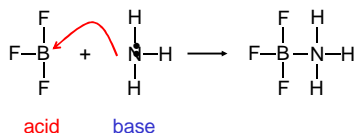
A **Lewis acid** is a substance that can accept a pair of electrons

A **Lewis base** is a substance that can donate a pair of electrons



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## Lewis Acids and Bases



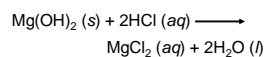
No protons donated or accepted!

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## Chemistry In Action: Antacids and the Stomach pH Balance

### Some Common Commercial Antacid Preparations

Commercial Name	Active Ingredients	$\text{NaHCO}_3 (aq) + \text{HCl} (aq) \longrightarrow \text{NaCl} (aq) + \text{H}_2\text{O} (l) + \text{CO}_2 (g)$
Alka-2	Calcium carbonate	
Alka Seltzer	Aspirin, sodium bicarbonate, citric acid	
Buflenin	Aspirin, magnesium carbonate, aluminum glycinate	
Buffered aspirin	Aspirin, magnesium carbonate, aluminum hydroxide-glycine	
Milk of magnesia	Magnesium hydroxide	
Rolaids	Dihydroxy aluminum sodium carbonate	
Tums	Calcium carbonate	



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