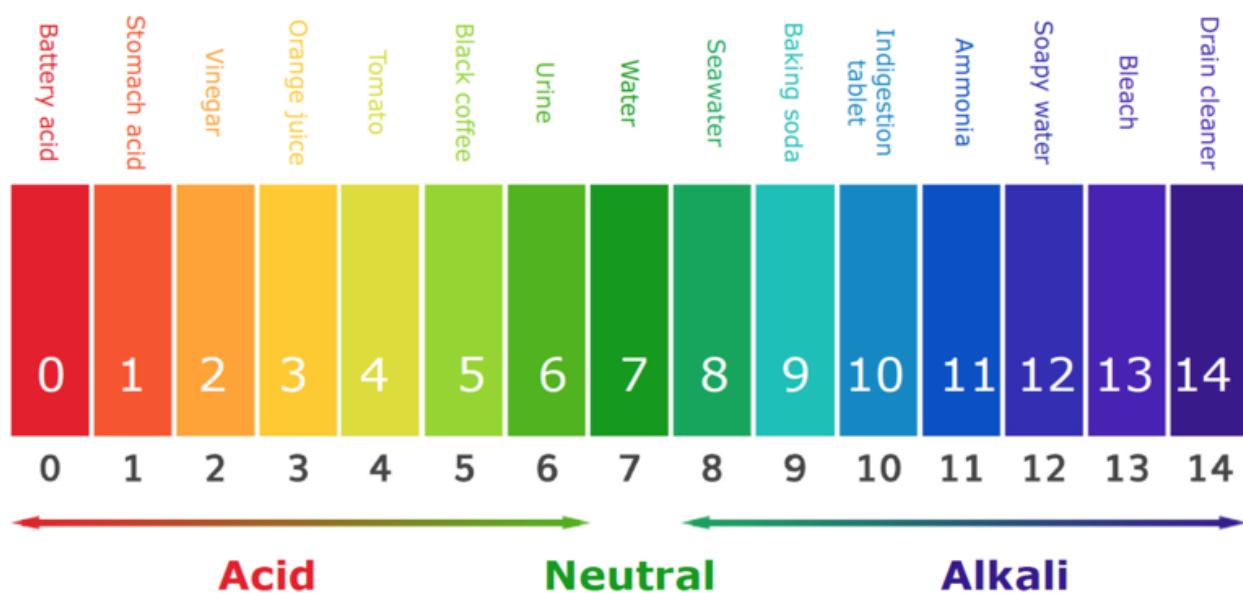


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Chapter3: Acids and Bases

Section 2: Strengths of Acids and Bases

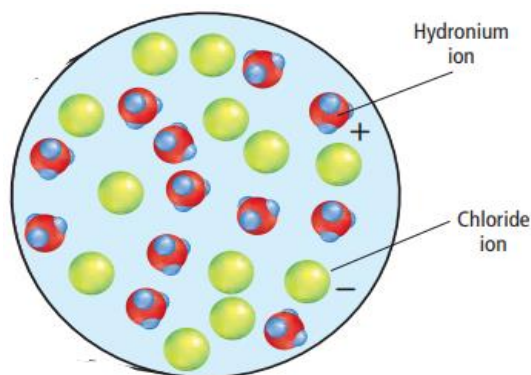


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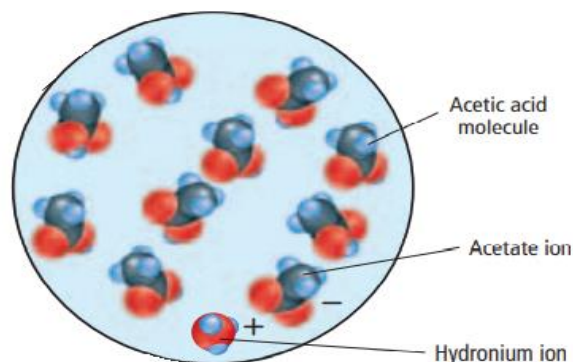
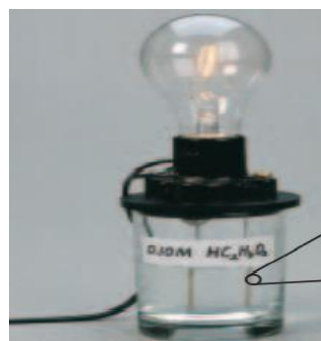
Section 2: Strengths of Acids and Bases

Strengths of Acids

- One of the properties of acidic and basic solutions is that they conduct electricity.
- Suppose you test the electrical conductivities of 0.10M aqueous solutions of hydrochloric acid and acetic acid.
- The glow of the bulbs in Figure indicate that the solutions conduct electricity.
- However, the brightness of the bulb connected to the HCl solution is larger than that of the bulb connected to the $\text{HC}_2\text{H}_3\text{O}_2$ solution.
- The 0.10M HCl solution conducts electricity better than the 0.10M $\text{HC}_2\text{H}_3\text{O}_2$ solution.
- Why is this true if the concentrations of the two acids are both 0.10M?
- Because ions carry electric current through the solution and all the HCl molecules contained in the solution are ionized completely into hydronium ions and chloride ions.
- **Strong acids** : Acids that ionize completely in solution .
- Because strong acids produce the maximum number of ions, they are good conductors of electricity and strong electrolyte.

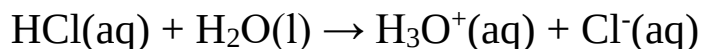


The light glows brightly when electrodes are placed in 0.10M hydrochloric acid solution because all of the HCl is in the form of hydronium ions and chloride ions.

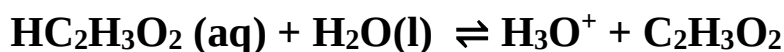


When electrodes are placed in 0.10M acetic acid solution, the light is dim.

- The ionization of hydrochloric acid in water can be represented by the following equation, which has a single arrow pointing to the right.
- Recall that a single arrow means that a reaction goes to completion.



- the weakly lit bulb of the apparatus containing the $\text{HC}_2\text{H}_3\text{O}_2$ solution this must mean that the acetic acid solution has fewer ions.
- **A weak acid** : an acid that ionizes only partially in dilute aqueous solution .
- Weak acids produce fewer ions and thus cannot conduct electricity as well as strong acids. Weak acid is called weak electrolyte.
- The ionization of acetic acid in water can be represented by the following equation, which has a double arrow this means that the reaction is reversible.



- **Ionization equations for some common weak acids**

Ionization Equations

Strong Acids		Weak Acids	
Name	Ionization Equation	Name	Ionization Equations
Hydrochloric	$\text{HCl} \rightarrow \text{H}^+ + \text{Cl}^-$	Hydrofluoric	$\text{HF} \rightleftharpoons \text{H}^+ + \text{F}^-$
Hydroiodic	$\text{HI} \rightarrow \text{H}^+ + \text{I}^-$	Acetic	$\text{HC}_2\text{H}_3\text{O}_2 \rightleftharpoons \text{H}^+ + \text{C}_2\text{H}_3\text{O}_2^-$
Perchloric	$\text{HClO}_4 \rightarrow \text{H}^+ + \text{ClO}_4^-$	Hydrosulfuric	$\text{H}_2\text{S} \rightleftharpoons \text{H}^+ + \text{HS}^-$
Nitric	$\text{HNO}_3 \rightarrow \text{H}^+ + \text{NO}_3^-$	Carbonic	$\text{H}_2\text{CO}_3 \rightleftharpoons \text{H}^+ + \text{HCO}_3^-$
Sulfuric	$\text{H}_2\text{SO}_4 \rightarrow \text{H}^+ + \text{HSO}_4^-$	Hypochlorous	$\text{HClO} \rightleftharpoons \text{H}^+ + \text{ClO}^-$

- **Describe the contents of dilute aqueous solutions of the strong acid HI and the weak acid HCOOH and write ionization equations.**

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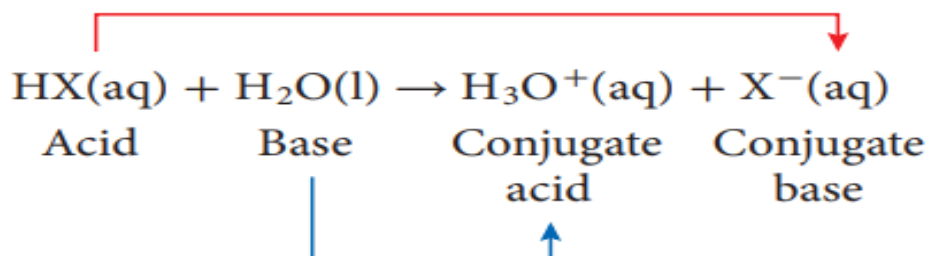
Acid strength and the Brønsted-Lowry model

- **Remember** that the acid on the reactant side of the equation produces a conjugate base on the product side. Similarly, the base on the reactant side produces a conjugate acid.

The idea revolves around the H^+ positive hydrogen ion:

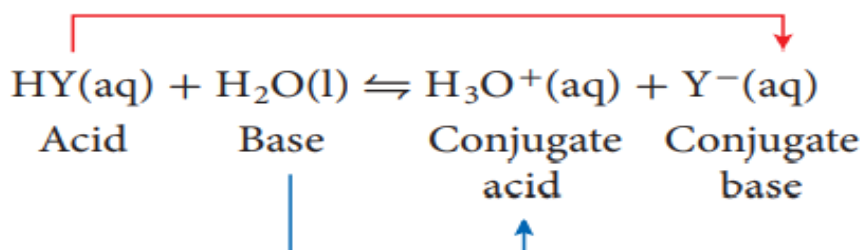
- The stronger the acid, the more easily it can give off a hydrogen ion, and the weaker the acid the more difficulty it is to give off the hydrogen ion.
- The base is strong the more it accepts the hydrogen ion. and the weaker base the more difficulty it accepts the hydrogen ion.
- Strong acid produces a weak conjugate base, Strong base produces a weak conjugate acid and vice versa.
- The equilibrium shifts to weak acid and weak base.
- When water reacts with strong acid, it becomes strong base.
- When water reacts with weak acid, it becomes weak base.

The ionization of any strong acid, HX.

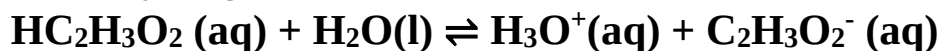


- HX represents a strong acid and its conjugate base is weak.
- That is, HX is nearly 100% ionized because H_2O is a stronger base (in the forward reaction) than is the conjugate base X^- (in the reverse reaction).
- **In other words**, the ionization equilibrium lies almost completely to the right because the base H_2O has a much greater attraction for the H^+ ion than does the base X^- .
- **Think of this as the battle of the bases:** Which of the two (H_2O or X^-) has a greater attraction for the hydrogen ion?
- **In the case of all strong acids, water is the stronger base.**
- **Notice that** the equation is shown with a single arrow to the right.

The ionization of any weak acid, HY.



- HY represents a weak acid and its conjugate base is strong.
- **In the battle of the bases**, the conjugate base Y^- (in the reverse reaction) is stronger than the base H_2O (in the forward reaction) and manages to capture the H^+ ion.
- The ionization equilibrium for a weak acid lies far to the left because the conjugate base Y^- has a greater attraction for the H^+ ion than does the base H_2O .
- In the case of acetic acid, the conjugate base $\text{C}_2\text{H}_3\text{O}_2^-$ (in the reverse reaction) has a stronger attraction for hydrogen ions than does the base H_2O (in the forward reaction).



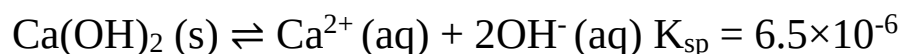
- **Notice that** the equation is shown with equilibrium arrows.

Strengths of Bases

- What you have read about acids can be applied to bases, except that OH^- ions, rather than H^+ ions, are involved.
- For example, the conductivity of a base depends on the extent to which the base produces OH^- ions in aqueous solution.

Strong bases

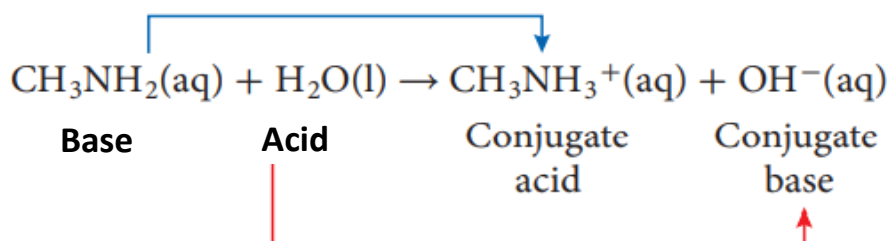
- A base that dissociates entirely into metal ions and hydroxide ions is known as a strong base.
- Therefore, metallic hydroxides, such as sodium hydroxide (NaOH), are strong bases.
$$\text{NaOH(s)} \rightarrow \text{Na}^+(\text{aq}) + \text{OH}^-(\text{aq})$$
- Some metallic hydroxides, such as calcium hydroxide (Ca(OH)_2) have low solubility and thus are poor sources of OH^- ions.
- **Note that** the solubility product constant K_{sp} , for calcium hydroxide (Ca(OH)_2) is small, indicating that few OH^- ions are present in a saturated solution.



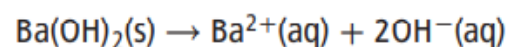
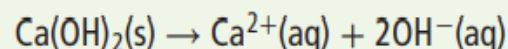
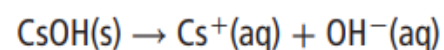
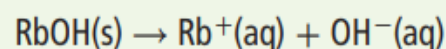
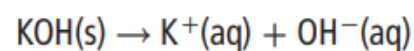
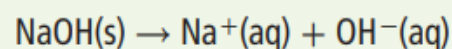
- Calcium hydroxide and other slightly soluble metallic hydroxides are considered strong bases because all of the compound that dissolves is completely dissociated.
- **The dissociation equations for several strong bases are listed in Table .**

Weak bases

- In contrast to strong bases, a weak base ionizes only partially in dilute aqueous solution.
- For example, methylamine (CH_3NH_2) reacts with water to produce an equilibrium mixture of CH_3NH_2 molecules, $\text{CH}_3\text{NH}_3^{+}$ ions, and OH^{-} ions.



Dissociation Equations for Strong Bases



- This equilibrium lies far to the left because the base, CH_3NH_2 , is weak and the conjugate base, OH^{-} ion, is strong.
- The hydroxide ion has a greater attraction for a hydrogen ion than a molecule of methyl amine has.

Ionization Constants of Weak Bases

Base	Ionization Equation	K_b (298 K)
Ethylamine	$\text{C}_2\text{H}_5\text{NH}_2(\text{aq}) + \text{H}_2\text{O}(\text{l}) \rightleftharpoons \text{C}_2\text{H}_5\text{NH}_3^{+}(\text{aq}) + \text{OH}^{-}(\text{aq})$	5.0×10^{-4}
Methylamine	$\text{CH}_3\text{NH}_2(\text{aq}) + \text{H}_2\text{O}(\text{l}) \rightleftharpoons \text{CH}_3\text{NH}_3^{+}(\text{aq}) + \text{OH}^{-}(\text{aq})$	4.3×10^{-4}
Ammonia	$\text{NH}_3(\text{aq}) + \text{H}_2\text{O}(\text{l}) \rightleftharpoons \text{NH}_4^{+}(\text{aq}) + \text{OH}^{-}(\text{aq})$	2.5×10^{-5}
Aniline	$\text{C}_6\text{H}_5\text{NH}_2(\text{aq}) + \text{H}_2\text{O}(\text{l}) \rightleftharpoons \text{C}_6\text{H}_5\text{NH}_3^{+}(\text{aq}) + \text{OH}^{-}(\text{aq})$	4.3×10^{-10}

Revision:

1- Write ionization equations for each acid.

a. HClO_2

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b. HNO_2

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c. HIO

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2- Write the first and second ionization equations for H_2SeO_3

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3- Write ionization equations for the following bases.

a. hexylamine ($\text{C}_6\text{H}_{13}\text{NH}_2$)

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b. propylamine ($\text{C}_3\text{H}_7\text{NH}_2$)

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c. carbonate ion (CO_3^{2-})

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d. hydrogen sulfite ion (HSO_3^-)

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5- Challenge Write an equation for a base equilibrium in which the base in the forward reaction is PO_4^{3-} and the base in the reverse reaction is OH^- .

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6- Relate the strength of a weak acid to the strength of its conjugate base.

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7- Identify the conjugate acid-base pairs in each equation.



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8- Explain the difference between a strong acid and a weak acid.

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9- Explain why equilibrium arrows are used in the ionization equation.

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10- Which of the beakers shown in Figure might contain a solution of 0.1M hypochlorous acid? Explain your answer.

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11- Identify the conjugate acid-base pairs in the reaction of H_3PO_4 with water.

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12- Write the chemical equation for the ionization of ammonia in water. How is it safe for a window cleaner to use a solution of ammonia, which is basic?

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13- Write the chemical equation for the ionization of aniline in water. Aniline is a weak base with the formula $\text{C}_6\text{H}_5\text{NH}_2$.

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14- Which of the components of an aqueous solution of acetic acid has the highest concentration?

- a- CH_3COO^- b- CH_3COOH c- H_3O^+ d- H^+

15- Which acid that aqueous solution contains its particles and ions together?

- a- HCl b- HI c- HBr d- HF

16- The conjugate base for OH^- is:

- a- O_2 b- O^{2-} c- H_3O^+ d- H_2O

17- The acid used for dyeing, engraving and hardening of steel has the formula:

- a- H_2SO_3 b- H_2SO_4 c- HCN d- H_3PO_4

18- Many organic compounds that contain nitrogen such as aniline $\text{C}_6\text{H}_5\text{NH}_2$ are:

- a- Strong bases b- weak bases c- strong acids d- weak acids

19- The amphoteric substance of the following is:

- a- PO_4^{3-} b- HPO_4^{2-} c- H_3O^+ d- H_3PO_4