ACID BASE CONCEPT: ARRHENIUS THEORY

PREREQUISITE

- Basics of acids and bases
- Definition and properties

LEARNING OUTCOME

- Knowledge of acids an bases
- Knowledge of electrolytic solutions
- Knowledge of slat solutions

Acids and bases have distinct properties.

- Acids give foods a tart or sour taste.
- Aqueous solutions of acids are strong or weak electrolytes.
- Acids cause certain dyes, called indicators, to change color.
- Many metals, such as zinc and magnesium, react with aqueous solutions of acids to produce hydrogen gas.

Acids and bases have distinct properties.

- Soap is a familiar material that has the properties of a base.
  - The bitter taste is a general property of bases.
  - The slippery feel of soap is another property of bases.
- Bases will cause an indicator to change color.
- Bases also form aqueous solutions that are strong or weak electrolytes.

Arrhenius Acids and Bases

In 1887, the Swedish chemist Svante Arrhenius proposed a new way of defining and thinking about acids and bases.

According to Arrhenius, acids are hydrogen-containing compounds that ionize to yield hydrogen ions (H^+) in solution. Bases are compounds that ionize to yield hydroxide ions (OH^-) in aqueous solution.

Arrhenius Acids

Acids vary in the number of hydrogens they contain that can form hydrogen ions.

Some Common Acids	
Name	**Formula**
Hydrochloric acid	HCl
Nitric acid	HNO_3
Sulfuric acid	H_2SO_4
Phosphoric acid	H_3PO_4
Ethanoic acid	CH_3COOH
Carbonic acid	H_2CO_3

Arrhenius Acids

A hydrogen atom that can form a hydrogen ion is described as *ionizable*.

- Nitric acid (HNO_3) has one ionizable hydrogen. Nitric acid is classified as a *monoprotic* acid.
  - The prefix *mono-* means “one,” and the stem *protic* reflects the fact that a hydrogen ion is a proton.

Arrhenius Acids

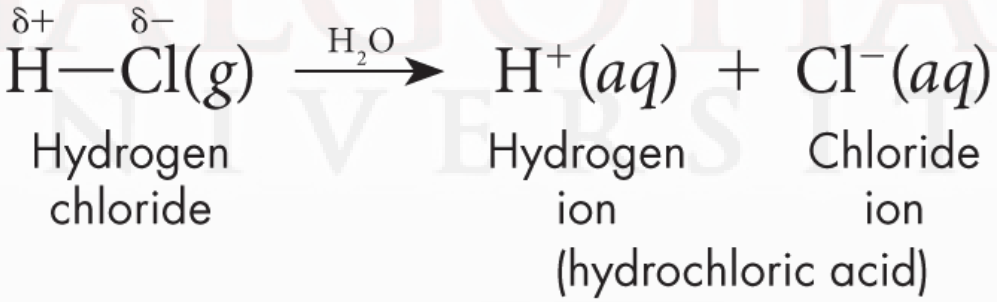
A hydrogen atom that can form a hydrogen ion is described as *ionizable*.

- Nitric acid (HNO_3) has one ionizable hydrogen. Nitric acid is classified as a *monoprotic* acid.
- Acids that contain two ionizable hydrogens, such as sulfuric acid (H_2SO_4), are called *diprotic* acids.
- Acids that contain three ionizable hydrogens, such as phosphoric acid (H_3PO_4), are called *triprotic* acids.

Arrhenius Acids

Not all compounds that contain hydrogen are acids.

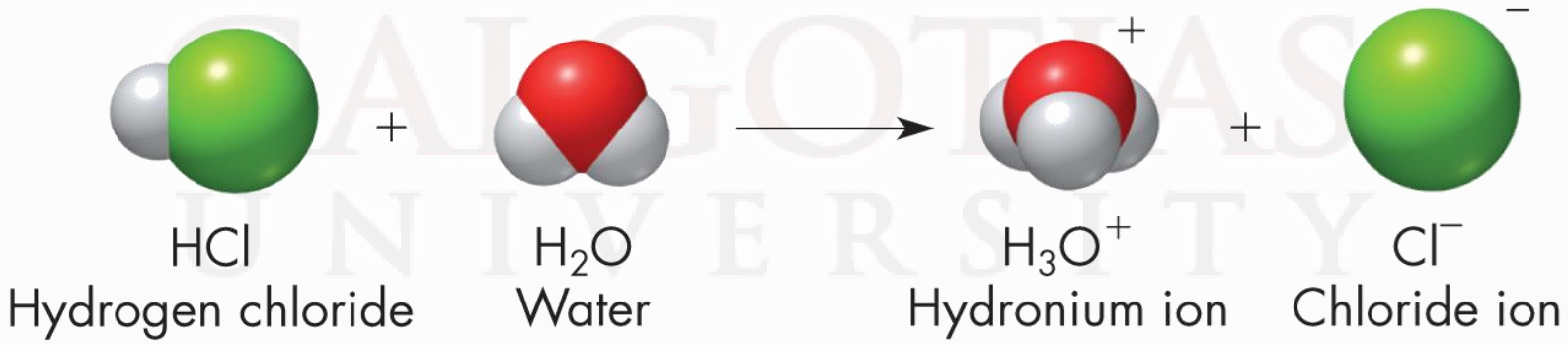
- Only a hydrogen that is bonded to a very electronegative element can be released as an ion. Such bonds are highly polar.
- When a compound that contains such bonds dissolves in water, it releases hydrogen ions.



Arrhenius Acids

In an aqueous solution, hydrogen ions are not present. Instead, the hydrogen ions are joined to water molecules as hydronium ions.

- A **hydronium ion (H_3O^+)** is the ion that forms when a water molecule gains a hydrogen ion.



Arrhenius Acids

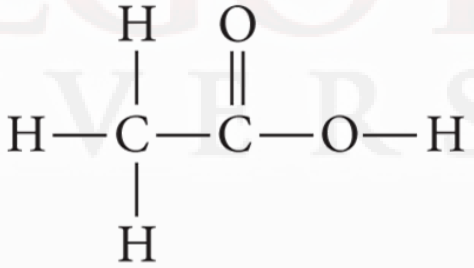
Methane (CH_4) is an example of a hydrogen-containing compound that is not an acid.

- The four hydrogen atoms in methane are attached to the central carbon atom by weakly polar C—H bonds.
- Methane has no ionizable hydrogens and is not an acid.

Arrhenius Acids

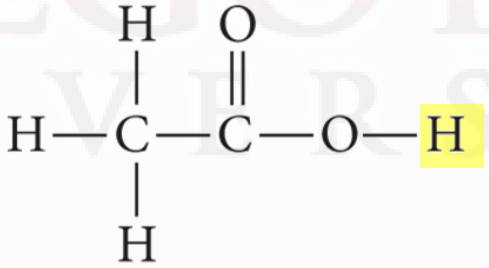
Ethanoic acid (CH_3COOH), which is commonly called acetic acid, is an example of a molecule that contains both hydrogens that do not ionize and a hydrogen that does ionize.

- Although its molecules contain four hydrogens, ethanoic acid is a monoprotic acid.



Arrhenius Acids

- The three hydrogens attached to a carbon atom are in weakly polar bonds.
  - They do not ionize.
- Only the hydrogen bonded to the highly electronegative oxygen can be ionized.



Arrhenius Bases

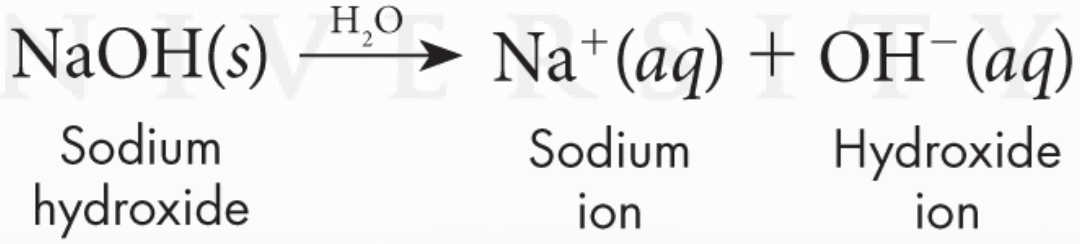
The table below lists four common bases.

Some Common Bases		
Name	**Formula**	**Solubility in Water**
Sodium hydroxide	NaOH	High
Potassium hydroxide	KOH	High
Calcium hydroxide	$Ca(OH)_2$	Very low
Magnesium hydroxide	$Mg(OH)_2$	Very low

Arrhenius Bases

The base sodium hydroxide (NaOH) is known as lye.

- Sodium hydroxide is an ionic solid.
- It dissociates into sodium ions in aqueous solution.



Arrhenius Bases

The base sodium hydroxide (NaOH) is known as lye.

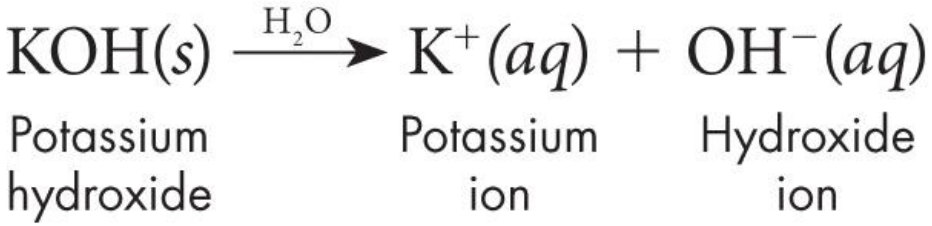
- Sodium hydroxide is extremely caustic.
  - A caustic substance can burn or eat away materials with which it comes in contact.
  - This property is the reason that sodium hydroxide is a major component of products that are used to clean clogged drains.

$$\underset{\text{Sodium hydroxide}}{NaOH(s)} \xrightarrow{H_2O} \underset{\text{Sodium ion}}{Na^+(aq)} + \underset{\text{Hydroxide ion}}{OH^-(aq)}$$

Arrhenius Bases

Potassium hydroxide (KOH) is another ionic solid.

- It dissociates to produce potassium ions and hydroxide ions in aqueous solution.



Arrhenius Bases

Sodium and potassium are Group 1A elements. Elements in Group 1A, the alkali metals, react violently with water.

- The products of these reactions are aqueous solutions of a hydroxide and a hydrogen gas.

$$2Na(s) + 2H_2O(l) \longrightarrow 2NaOH(aq) + H_2(g)$$

Sodium metal — Water — Sodium hydroxide — Hydrogen

Arrhenius Bases

Sodium hydroxide and potassium hydroxide are very soluble in water.

- The solutions would typically have the bitter taste and slippery feel of a base, but you would not want to test these properties.
- The solutions are extremely caustic to the skin. They can cause deep, painful, slow-healing wounds if not immediately washed off.

Can every hydrogen from every molecule form hydrogen ions, therefore acting as an Arrhenius acid?

No. Only hydrogens that are bonded to a very electronegative element can be released as ions. That means that only molecules containing hydrogens bonded to very electronegative elements are Arrhenius acids.

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- Rayner-Canham, G. (1994). Concepts of Acids and Bases. *Journal of College Science Teaching*, *23*(4), 246-47.