Chapter 9 – Acids & Bases

9.1 Arrhenius Acids and Bases

- <u>Arrhenius Acid</u>: substance that produces H^+ ions in aqueous solutions.

  $HCl\ (aq) \rightarrow H^+\ (aq) + Cl^-\ (aq)$

- <u>Arrhenius Base</u>: substance that produces OH^- ions in aqueous solutions.

  $NaOH\ (aq) \rightarrow Na^+\ (aq) + OH^-\ (aq)$

PROPERTIES OF ACIDS AND BASES

Properties of Arrhenius Acids	Properties of Arrhenius Bases
▪ **Produce H^+ ions in water**	▪ **Produce OH^- ions in water**
▪ Taste sour ▪ Act corrosive ▪ Turn blue litmus turns red	▪ Taste bitter ▪ Feel slippery ▪ Turn red litmus turn blue

- **<u>Neutralization Reactions</u>**

⇒ Some acid base reactions look like this: ACID + BASE → SALT + H_2O

$HCl\ (aq) + NaOH\ (aq) \rightarrow NaCl\ (aq) + H_2O\ (l)$

Salt - ionic compound formed during acid-base neutralization reaction.

Example: For the reaction: $2HNO_3\ (aq) + Ca(OH)_2\ (aq) \rightarrow 2H_2O\ (l) + Ca(NO_3)_2\ (aq)$

________ is the Arrhenius acid, and _________ is the Arrhenius base.

(Answer: HNO_3 is the acid, $Ca(OH)_2$ is the base)

9.2 Bronsted-Lowry Acids and Bases

Bronsted-Lowry acid-base reactions involve a transfer of a proton (H^+) from an acid to a base.

- <u>Bronsted - Lowry Acid:</u> proton donor (loses H^+)

- <u>Bronsted - Lowry Base:</u> proton acceptor (gains H^+)
  - ✓ This definition allows for a broader range of bases to be included.

Examples: 1) $HCl\ (aq) + H_2O\ (l) \rightarrow H_3O^+\ (aq) + Cl^-\ (aq)$

2) $NH_3\ (aq) + HBr\ (aq) \rightarrow NH_4^+\ (aq) + Br^-\ (aq)$

(Answers: 1. HCl is BLA, H_2O is BLB; 2. NH_3 is BLB, HBr is BLA)

9.3 Strong Acids and Bases

⇒ Strong acids ionize almost completely (~100%) in water: HCl, HNO_3, H_2SO_4

$$HCl\ (aq) \rightarrow H^+\ (aq) + Cl^-\ (aq)$$

Almost all the HCl molecules break apart to form H^+ ions and Cl^- ions

✓ 100 % of acid molecules have ionized

HCl = hydrochloric acid, HNO_3 = nitric acid, H_2SO_4 = sulfuric acid

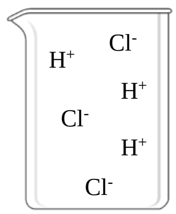
⇒ Strong bases dissociate almost completely (~100%) to form ions: KOH, NaOH

$$NaOH\ (aq) \rightarrow Na^+(aq) + OH^-(aq)$$

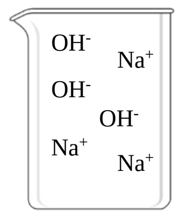
Almost all the NaOH units break apart and dissociate completely 100% to form ions

KOH = potassium hydroxide, NaOH = sodium hydroxide

Examples:



HCl (aq)



NaOH (aq)

9.4 Weak Acids and Bases

⇒ Weak acids ionize very little (~1-5 %) in water: HF, H_2CO_3, H_3PO_4, $HC_2H_3O_2$

$$HC_2H_3O_2\ (aq) \leftrightarrows H^+\ (aq) + C_2H_3O_2^-\ (aq)$$

Most of the $HC_2H_3O_2$ molecules do not break apart to form ions

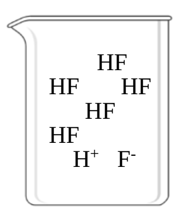
✓ only ~ 1 % of the acid molecules have ionized

HF = hydrofluoric acid, H_2CO_3 = carbonic acid, H_3PO_4 = phosphoric acid, $HC_2H_3O_2$ = acetic acid

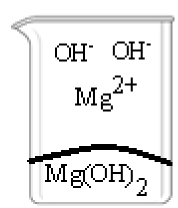
⇒ Weak bases dissociate very little (~1-5%) so just a few ions are formed: $Mg(OH)_2$ Name is magnesium hydroxide

$$Mg(OH)_2\ (s) \leftrightarrows Mg^{2+}\ (aq) + 2\ OH^-\ (aq)$$

Examples:



HF (aq)



$Mg(OH)_2$ (aq)

9.5 pH Scale

pH scale: expresses H^+ concentrations on a scale that ranges from 0 -14.

A pH value indicates how acidic or basic a solution is:

Acidic: pH < 7 Neutral: pH= 7 Basic: pH > 7

⇒ The following formula gives the relationship between $[H^+]$ and pH:

$$pH = -\log[H^+] \quad \text{or} \quad [H^+] = 10^{-pH}$$

[ ] means concentration or molarity in units of moles / liter

- $[H^+]$ = the moles / Liter of H^+ ions
- $[OH^-]$ = the moles / Liter of OH^- ions
    - In pure water, $[H^+] = [OH^-]$
    - In acidic solution $[H^+] > [OH^-]$
    - In basic solution $[H^+] < [OH^-]$

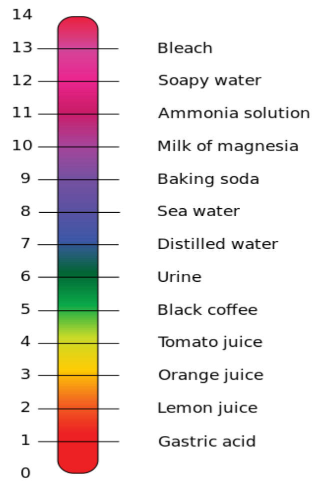


Image: CC BY 3.0 https://commons.wikimedia.org/wiki/File:PH_Scale.svg#filelinks

Example: If $[H^+] = 10^{-5}$, then pH = 5.

Example: If $[H^+] = 0.0001$, then pH = ?

- *To find the pH make sure to convert the concentration to scientific notation:*

Express 0.0001 in scientific notation: $[H^+] = 10^{-4}$ so pH = 4

9.6 Buffers

Buffer: A solution that resists changes in pH when a small amount of an acid or base is added.

⇒ Buffer systems are very important for maintaining the pH of biological fluids.

⇒ blood pH needs to stay around a pH value of 7.4 or death can result.

9.7 Solubility Rules

Solubility: An amount of solute that can dissolve in a given amount of solvent.

⇒ Solubility rules are for an ionic solid placed in water at 25°C.

- **Soluble**: The ionic compound dissolves completely.
    - The ionic compound is given the designation aqueous (aq) as its physical state.

- **Insoluble**: The ionic compound does not dissolve much - only a very small percent dissolves.
    - The ionic compound is given the designation solid (s) as its physical state.

Solubility Rules

Generally **soluble** compounds with:

1. Li^+, Na^+, K^+, NH_4^+ (**ALWAYS!**)
2. acetate ion ($C_2H_3O_2^-$)
3. nitrate ion (NO_3^-)
4. halide ions (X): Cl^-, Br^-, and I^-
   BUT AgX, HgX_2, PbX_2 are all **insoluble**
5. sulfate ion (SO_4^{2-}), BUT $CaSO_4$, $SrSO_4$, $BaSO_4$, Ag_2SO_4, $PbSO_4$ are all **insoluble**

Generally **insoluble** compounds with:

6. carbonate ion (CO_3^{2-})
7. chromate ion (CrO_4^{2-})
8. phosphate ion (PO_4^{3-})
9. sulfide ion (S^{2-})
   BUT CaS, SrS, BaS are all **soluble**
10. hydroxide (OH^-), BUT $Ca(OH)_2$, $Sr(OH)_2$, $Ba(OH)_2$, are all **soluble**

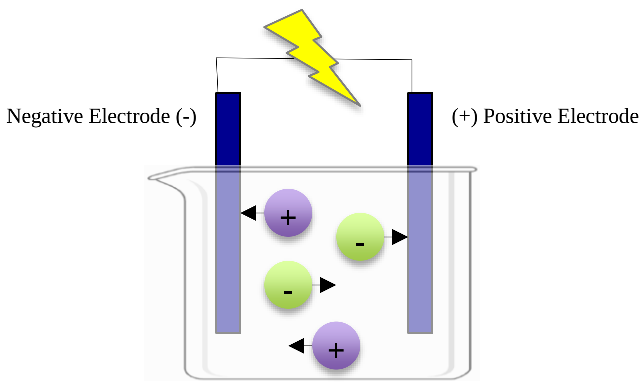
Example:

Determine if the following are soluble or insoluble in water and write the correct physical state next to each:

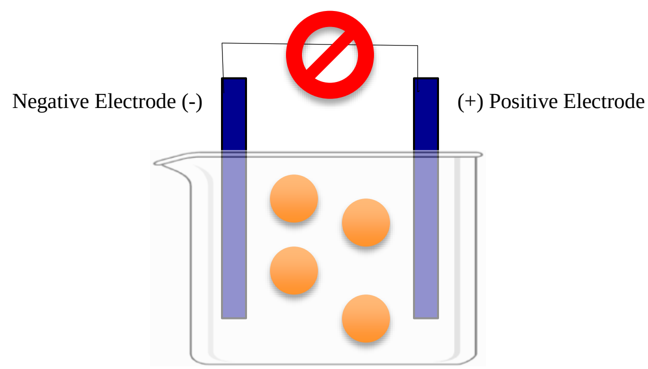
1. Na_2S ______ soluble insoluble
2. $Al(OH)_3$ ______ soluble insoluble
3. AgBr ______ soluble insoluble
4. $CaCO_3$ ______ soluble insoluble
5. KNO_3 ______ soluble insoluble

9.8 Electrolytes

Electrolyte: A substance that once dissolved in water, conducts electricity by the net movement of ions.



Electrolyte: Net movement of ions conducts electricity.



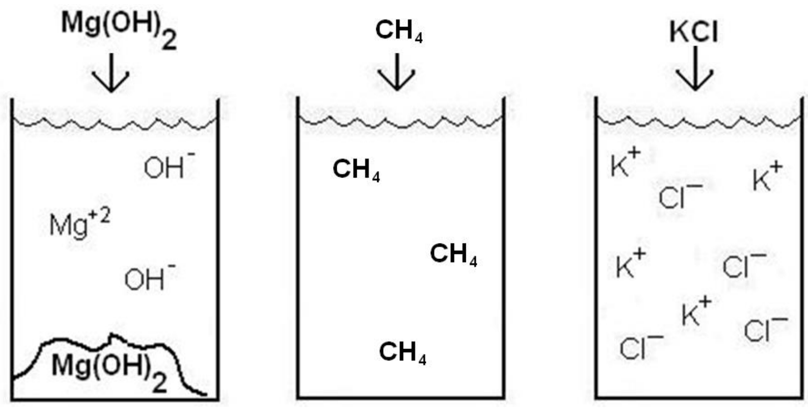
Nonelectrolyte: No ions present. Electricity is not conducted.

- **<u>Strong electrolyte</u>** - a solution that is a good conductor of electricity.
  - Substance that totally dissociates or ionizes in water. (All ions)
    - Soluble ionic compounds (e.g. NaCl, KBr, $LiNO_3$, $NaC_2H_3O_2$)
    - Strong acids (e.g. HCl, HBr, HNO_3, HI)
    - Strong bases (e.g. NaOH, KOH, LiOH, $Ca(OH)_2$)

- **<u>Weak Electrolyte</u>** - solution that conducts electricity poorly.
  - Substance partially ionizes in water (few ions)
    - Insoluble ionic compounds (e.g. AgCl, $Ca_3(PO_4)_2$)
    - Weak acids (e.g. HF, H_2CO_3)
    - Weak bases (e.g. NH_3, $Mg(OH)_2$)

- **<u>Nonelectrolyte</u>** - solution that does not conduct electricity.
  - Neutral molecules are present in solution. (**No ions!**)
    - Molecular compounds such as H_2O, $C_6H_{12}O_6$ (sugar), I_2

Examples:



Weak Electrolyte   Nonelectrolyte   Strong Electrolyte

BE ABLE to DRAW BEAKERS of WATER with ELECTROLYTES in THEM

NaCl	http://www.youtube.com/watch?v=aELPrWzixeU
HCl vs acetic acid	http://www.youtube.com/watch?v=NdG3wK9kNcg&feature=related
Strong vs weak base	http://www.youtube.com/watch?v=Av1LUAPN5q8&feature=related
Strong vs weak acid	http://www.youtube.com/watch?v=kcPjY9cQpWs&feature=related

For Fun

- Blood pH needs to be between 7.35 and 7.45
- Maintained by CO_2 / HCO_3^- buffer system
  - –Breathing can affect change in this system in seconds
- Acidosis is excess acid. Results in heavy breathing, weakness, headache, coma, and pH < 6.8=death.
- Alkalosis is excess base. Results in convulsions, muscular weakness, and pH>7.8 = death
- Partial pressure of CO_2 normal is 35-45 mmHg
- High P_{CO_2} means acidosis (lots of CO_2 in blood)
- Low P_{CO_2} means alkalosis (little CO_2 in blood)
- Buffer rxn: $CO_2 + H_2O \leftrightarrows H_2CO_3 \leftrightarrows H^+ + HCO_3^-$

☺

CHAPTER 9 PRACTICE PROBLEMS

1. Are the following acidic, basic or neutral?

   pH = 3, pH = 7, pH = 11, pH = 1

2. Indicate the Arrhenius acid and base in each of the following reactions:

   a. $2\ HNO_3(aq) + Ca(OH)_2(aq) \rightarrow 2\ H_2O(l) + Ca(NO_3)_2(aq)$

   b. $HI(aq) + KOH(aq) \rightarrow H_2O(l) + KI(aq)$

3. Indicate the Brønsted-Lowry acid and base in each of the following reactions:

A) H_2O (l) + NH_3 (aq) ⇆ NH_4^+ (aq) + OH^- (aq)

B) HSO_3^- (aq) + HNO_3 (aq) → H_2SO_3 (aq) + NO_3^- (aq)

C) $H_2PO_4^-$ (aq) + H_2SO_4 (aq) → H_3PO_4 (aq) + HSO_4^- (aq)

4. A) $[H^+]$=0.00001 M means pH = ___________

B) $[H^+]$=0.000001 M means pH = ___________

C) $[H^+]= 10^{-10}$ M means pH = ___________

5. Classify these as non-, weak, or strong electrolytes and draw them in a beaker of water.

LiBr, PbI_2, $C_{12}H_{22}O_{11}$, KCl

Answers to Practice Problems

1. 3 is acidic, 7 is neutral, 11 is basic, 1 is acidic
2. a. acid = HNO_3 and base = $Ca(OH)_2$ b. acid = HI and base = KOH
3. A) acid = H_2O, base = NH_3, B) acid = HNO_3, base = HSO_3^-

   C) acid = H_2SO_4, base = $H_2PO_4^-$
4. a) pH = 5, B) pH = 6, C) pH = 10
5. LiBr is strong, PbI_2 is weak, $C_{12}H_{22}O_{11}$ is non, KCl is strong