Acids and Bases

By Peter S. Cartwright, PE, CWS-VI

The basic chemistry fundamentals presented every month is not intended to be a comprehensive chemistry course, but rather basic instruction on chemistry as it relates to water and water treatment. It is hoped that your interest will be piqued and induce you to want to learn more. The desired outcome is that it will help you become a more effective and valuable water treatment professional. Please get back to us with any questions or concerns; we welcome your input!

Acids are compounds that release hydrogen ions (H^+) in solution (e.g: hydrochloric acid, sulfuric acid, etc.). It is the H^+ ion that gives acids their properties; the greater the H^+ ion concentration, the stronger the acid.

$HCl \rightarrow H^+ + Cl^-$

$H_2SO4 \rightarrow 2H^+ + SO_4^{2-}$

Bases are compounds that release hydroxide (OH^-) ions in solution (e.g: calcium hydroxide [slaked lime], sodium hydroxide, ammonium hydroxide, etc.). They produce a form of alkalinity.

$Ca\ (OH)_2 \rightarrow Ca^{2+} + 2OH^-$

$NaOH \rightarrow Na^+ + OH^-$

$NH_4OH \rightarrow NH_4^+ + OH^-$

Acids

Strong acids completely separate into their ions and stay separated. This is indicated by a single arrow pointing in one direction.

$HCl \rightarrow H^+ + Cl^-$

Weak acids and bases are in a continuous process of ionization, but free ions are also continuously recombining to form molecules.

CH_3COOH (vinegar) $\leftrightarrow H^+ + CH_2COOH^-$
(99.5 percent separated)

At any one time, only a portion of the acid or base is present as ions. This equilibrium process is indicated by arrows pointing in both directions.

The pH helps in predicting corrosion and scaling tendencies, but is not the only measure for these. At low pH (acidic) levels, the solution tends to be corrosive.

Strong/weak acids

Strong acids ionize 100 percent and include the following examples:

- HCl (Hydrochloric)
- HBr (Bromic)
- HI (Hydriodic)
- HNO_3 (Nitric)
- $HClO_4$ (Perchloric)
- H_2SO_4 (Sulfuric)

Weak acids do not ionize completely and include the following examples:

- $HC_2H_3O_2$ (Acetic)
- HCN (Hydrocyanic)
- $H_2B_4O_7$ (Boric)
- HNH_2SO_3 (Sulfamic)
- $C_6H_8O_7$ (Citric)
- H_3PO_4 (Phosphoric)
- HOCl (Hypochlorous)
- H_2CO_3 (Carbonic)

Strong/weak bases

Strong bases are alkaline compounds that ionize 100 percent. The term most familiar in water chemistry for bases dissolved in water is alkalinity.

The most common strong bases in water chemistry include the following:

- NaOH (Sodium hydroxide)
- KOH (Potassium hydroxide)
- $Ca(OH)_2$ (Calcium hydroxide)

Weak bases are alkaline compounds that do not ionize completely. There are a number of weak bases, not normally encountered in water treatment.

pH

While on the subject of acids and bases, it is important to introduce the subject of pH.

- pH stands for potential of hydrogen.
- pH is defined as "the negative log of hydrogen ion concentration" and indicates relative intensity on a scale of 1 to 14. Pure water has pH 7.

Concentration of hyrdrogen ions compared to distilled water		Examples of solutions at this pH
10,000,000	pH = 0	battery acid, strong hydrofluoric acid
1,000,000	pH = 1	hydrochloric acid secreted by stomach lining
100,000	pH = 2	lemon juice, gastric acid, vinegar
10,000	pH = 3	grapefruit, orange juice, soda
1,000	pH = 4	tomato juice, acid rain
100	pH = 5	soft drinking water, black coffee
10	pH = 6	urine, saliva
1	pH = 7	"pure" water
1/10	pH = 8	sea water
1/100	pH = 9	baking soda
1/1,000	pH = 10	Great Salt Lake, milk of magnesia
1/10,000	pH = 11	ammonia solution
1/100,000	pH = 12	soapy water
1/1,000,000	pH = 13	bleaches, oven cleaner
1/10,000,000	pH = 14	liquid drain cleaner

- The higher the hydrogen ion concentration, the greater the acidity.
- The lower the hydrogen ion concentration, the greater the alkalinity.
- pH 7 indicates neutral state.
- On the pH scale, each number is 10 times more or less acidic than the next adjacent number. Water with pH of 6 is 10 times more acidic than water with pH 7, with 100 times more alkaline than pH 4.

pH may determine whether certain compounds will precipitate out of solution or not. Many compounds become more insoluble at higher pH levels.

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About the author

Peter S. Cartwright, CWS-VI, President of Cartwright Consulting Company, of Minneapolis is a registered Professional Engineer in Minnesota. He has been in the water treatment industry since 1974, has authored over 125 articles, presented over 125 lectures in conferences around the world and has been awarded three patents. Cartwright has chaired several WQA committees and task forces and has received the organization's Award of Merit. A member of WC&P Technical Review Committee since 1996, his expertise includes such high-technology separation processes as RO, UF, MF, UF electrodialysis, deionization, carbon adsorption, ozonation and distillation. Cartwright is also Technical Consultant to the Canadian Water Quality Association. He can be reached by phone (952) 854-4911; fax (952) 854-6964; email pscartwright@msn.com or on his website, www.cartwright-consulting.com.