Electrolytes and Non-electrolytes

Electrolytes are solutes which ionize in a solvent to produce an electrically conducting medium. Strong electrolytes are completely ionized like HNO_3, HCl, NaOH, KOH, and most salts.

Weak electrolytes are partially ionized in the solvents like H_2CO_3, H_3BO_3, NH_4OH, halides, cyanides and thiocyanates of Hg, Zn and Cd.

Non- electrolytes are solutes which do not ionize in their solvent, and therefore , the solution does not conduct electricity. Examples are solutions of sugar, urea and ethanol in water.

Solutions

A solution is a mixture of one solute or more with a solvent or mixture of solvents . The solute is always the little amount and the solvent should be in large amount . When water is the solvent the solutions are called aqueous solutions like the solutions of sodium chloride, sugar, hydrochloric acid and sodium hydroxide in water. If the solvent is any material rather than water, the solution is called non-aqueous solution like the solution of I_2 in CCl_4 and the solution of sulphur in carbon disulphide (CS_2).

The solute may be a solid, liquid and gas materials. Solids in liquids and liquids in liquids solutions are the most solutions considered in this study.

Solutions are classified according to the nature of particles of the solute into: true solutions, suspended solutions and colloidal solutions.

True solutions : They are the solutions where the molecules or the ions of the solute disappear between the molecules of the solvent. Therefore, the solute particles are invisible by naked eye or microscope, don't settle in the bottom of the container, and passed through filter paper. These solutions are homogenous and transparent. Examples are solutions of NaCl in water , $KMnO_4$ in water and I_2 in ethanol.

Suspended solutions or Suspensions : The particles of the solute in these solutions can be distinguished by naked eye because they are heterogeneous solutions. The solute particles are separated and settled in the bottom of the container . Solute particles do not pass through filter paper . Examples are solutions of dust in water or powdered chalk in water.

Colloidal solutions : The solute particles in these solutions are suspended to the particles of the solvent and become heterogeneous solutions but the solute particles don't settle in the bottom of container while they pass through filter paper like true solutions. Solute particles can be isolated from solvent by parchment paper. However, the particles can be distinguished through ulramicroscope. Examples are milk, gelatin and Arabic gum.

Solutions are also classified into unsaturated, saturated and supersaturated solutions according to the amount of solute in solvent.

Unsaturated solutions : These are solutions where the amount of solute is not sufficient to bring them to saturated case. This means that the solvent can get extra amount of solute. Such as the solubility of 5 grams of NaCl in 100 ml of water at definite temperature.

Saturated solutions : Solutions which contain the sufficient amount of solute in sufficient volume of solvent. Any extra addition of the solute will settle in the bottom of the container at certain temperature such as sufficient amount of Na_2CO_3 in 100 ml of water at definite temperature.

Supersaturated solutions : Solutions contain extra amount of solutes at higher temperature of the saturated solutions. If the temperature is lowered, some amount of the solute will be separated and settled in the bottom of container. The three types of these solutions can be distinguished by adding a crystals of the solute to these solutions:

(i) If it dissolves , the solution is unsaturated.

(ii) If it settles , the solution is saturated.

(iii) If it grows and its size becomes larger ,the solution is supersaturated.

Acids, Bases and Salts

Arrhenius Definitions of Acids and Bases.

Arrhenius Acids

Acids are materials when dissolved in water they give hydrogen ions (protons):

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

$$HNO_3 \longrightarrow H^+ + NO_3^-$$

$$HClO_4 \longrightarrow H^+ + ClO_4^-$$

$$CH_3COOH \rightleftharpoons H^+ + CH_3COO^-$$

$$H_3BO_3 \rightleftharpoons H^+ + H_2BO_3^-$$

Hydrogen ions can not remain free in the solutions. They combine with water molecules to form hydronium ions (H_3O^+):

$$H^+ + H_2O: = H_2O: \longrightarrow H^+ \longrightarrow H_3O^+ \qquad \text{(hydronium ion)}$$

This combination is coordinated process since H_2O has unrelated pairs of electrons and H^+ is without electrons. This combination is similar to NH_4^+ formation:

$$:NH_3 + H^+ = H^+ \longleftarrow :NH_3 \longrightarrow NH_4^+ \qquad \text{(Ammonium ion)}$$

Therefore, the above ionization of acids can be rewritten as follows:

$$HCl + H_2O \longrightarrow H_3O^+ + Cl^-$$

$$HNO_3 + H_2O \longrightarrow H_3O^+ + NO_3^-$$

$$HClO_4 + H_2O \longrightarrow H_3O^+ + ClO_4^-$$

$$CH_3COOH + H_2O \rightleftharpoons H_3O^+ + CH_3COO^-$$

$$H_3BO_3 + H_2O \rightleftharpoons H_3O^+ + H_2BO_3^-$$

polyprotic acids:

These acids ionize in steps since they have more than one hydrogen ion. Examples are:

$$H_2SO_4 \longrightarrow HSO_4^- + H^+$$

<u>Or</u> $H_2SO_4 + H_2O \longrightarrow HSO_4^- + H_3O^+$

$$HSO_4^- \rightleftharpoons H^+ + SO_4^{2-}$$

<u>Or</u> $HSO_4^- + H_2O \rightleftharpoons H_3O^+ + SO_4^{2-}$

$$H_3PO_4 \rightleftharpoons H^+ + H_2PO_4^- \rightleftharpoons H^+ + HPO_4^{2-3}{}_4 + PO^+ H \rightleftharpoons -$$

<u>Or</u> $H_3PO_4 + H_2O \rightleftharpoons H_3O^+ + H_2PO_4^-$ Primary ionization

$H_2PO_4^- + H_2O \rightleftharpoons H_3O^+ + HPO_4^{2-}$ Secondary ionization

$HPO_4^{2-} + H_2O \rightleftharpoons H_3O^+ + PO_4^{3-}$ Tertiary ionization

A complete ionization acids are called strong acids :

$HCl \longrightarrow H^+ + Cl^-$ Or $HCl + H_2O \longrightarrow H_3O^+ + Cl^-$ $HClO_4 \longrightarrow H^+ + ClO_4^-$ Or $HClO_4 + H_2O \longrightarrow H_3O^+ + ClO_4^-$

A partial ionization acids are called weak acids :

$$CH_3COOH + H_2O \rightleftharpoons H_3O^+ + CH_3COO^-$$

$$HCOOH + H_2O \rightleftharpoons H_3O^+ + HCOO^-$$

$$HCN + H_2O \rightleftharpoons H_3O^+ + CN^-$$

$$H_2C_2O_4 + H_2O \rightleftharpoons H_3O^+ + HC_2O_4^-$$

$$HC_2O_4^- + H_2O \rightleftharpoons H_3O^+ + C_2O_4^{2-}$$

However, when the solutions of weak acids are very diluted, they become completely ionized and the anions are completely separated from hydronium ion. The behavior of weak acids then is similar to strong acids in this condition.

Arrhenius Bases

Bases are the materials when dissolved in water they give hydroxyl ion (OH^-). The bases are either strong or weak. Bases also are either mono hydroxyl group or poly hydroxyl groups. Examples are:

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

$$KOH \longrightarrow K^+ + OH^-$$

$$Mg(OH)_2 \longrightarrow Mg^{2+} + 2OH^-$$

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

$$Al(OH)_3 \rightleftharpoons Al(OH)_2^+ + OH^-$$

$$Al(OH)_2^+ \rightleftharpoons Al(OH)^{2+} + OH^-$$

$$Al(OH)^{2+} \rightleftharpoons Al^{3+} + OH^-$$

Solution of ammonia in water is a weak base of mono hydroxyl group :

$$NH_3 + H_2O \rightleftharpoons NH_4OH \rightleftharpoons NH_4^+ + OH^-$$

Definitions of acids and bases according to Bronsted-Lowry theory:

Acids are proton donor materials which involve the following species :

a- Uncharged molecules : CH_3COOH, H_2SO_4, $H_2C_2O_4$, HCl , HNO_3 and $HClO_4$.

b- Negatively charged species : HSO_4^-, $H_2PO_4^-$, $HCOO\text{-}COO^-$ which can be found as an acidic salts :$KHSO_4$, NaH_2PO_4 and HCOO-COONa .

c- Positively charged species :

$$NH_4^+ \rightleftharpoons H^+ + NH_3$$

$$H_3O^+ \rightleftharpoons H^+ + H_2O$$

Bases are proton accepter materials. These materials include the following species :

a- Uncharged molecules (like ammonia and amines)

$$NH_3 + H^+ \rightleftharpoons NH_4^+$$

$$RNH_2 + H^+ \rightleftharpoons RNH_3^+$$

b- Metal hydroxides which give hydroxyl ions :

$$OH^- + H^+ \rightleftharpoons H_2O$$

c- Negatively charged ions which obtained from weak acids:

$$CH_3COO^- + H^+ \rightleftharpoons CH_3COOH$$

$$HCOO^- + H^+ \rightleftharpoons HCOOH$$

Therefore for each acid there is corresponding base called conjugated base and for each base there is corresponding acid called conjugated acid. This relation is expressed in the following equation:

$$\text{Acid} \rightleftharpoons \text{Base} + \text{proton}$$

$$\text{Or} \quad A \rightleftharpoons B + H^+$$

Where A = conjugated acid and B = conjugated base. Some materials behave as acids in some reactions and bases in other reactions:

$$\underset{\text{acid}}{H_2O} + \underset{\text{base}}{H_2O} \rightleftharpoons \underset{\text{acid}}{H_3O^+} + \underset{\text{base}}{OH^-}$$

$$\underset{\text{acid}}{HCO_3^-} \rightleftharpoons H^+ + \underset{\text{conjugated base}}{CO_3^{2-}}$$

$$\underset{\text{base}}{HCO_3^-} + H^+ \rightleftharpoons \underset{\text{conjugated acid}}{H_2CO_3}$$

Definitions of Acids and Bases According to Lewis Idea:

Acid is an electron-pair accepter, examples are SO_3, $AlCl_3$, Ag^+, SiO_2, $SnCl_4$, H^+. Base is an electron-pair donor, Examples are OH^-, F^-, NH_3, -C=C-, -C≡C- and H^- .

Lewis concepts of acids and bases go further toward freeing acid-base behavior from involvement of protons and largely increase the number of processes that can be considered as acid-base reactions as well. The Lewis ideas are useful in describing organic reaction mechanisms but are too broad for useful application in analytical chemistry .

Salts

Salts are products of combination of cations and anions. Some of the salts are anhydrous materials like NaCl, KCl, $KMnO_4$ and $K_2Cr_2O_7$. Other salts are hydrous such as $CaCl_2.2H_2O$, $CuSO_4.5H_2O$, $Na_2B_4O_7$.10H2O and $ZnSO_4.7H_2O$

X-rays show that the salts are ionized in its solid state. Therefore, Sodium Chloride is ionized in its crystalline case into Na^+ which is surrounded by six ions of Cl^- , and Cl^- which is surrounded by six ions of Na^+. These ions are attached to each other by electrostatic strengths. Thus, these salts are completely ionized in solvent of high dielectric constant like water. Most of salts are strongs but weak salts were proved by X-rays such as $Hg(CN)_2$, $HgCl_2$, $Pb(CH_3COO)_2$, $CdCl_2$, $CdBr_2$ and CdI_2.