Chapter 4 – Aqueous Reactions and Solution Stoichiometry

Section 1 - Electrolytes

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Introduction - Aqueous Solutions

- **Solution** – A solution is a homogeneous mixture of solute and solvent.
  - Solute: the component that is dissolved.
  - Solvent: the component that does the dissolving (the larger quantity).
- Aqueous solutions are those in which water is the solvent.
- ***Dissociation*** occurs when ionic compounds separate into ions when dissolved in water:

$$NaCl_{(s)} \rightarrow Na^{+}_{(aq)} + Cl^{-}_{(aq)}$$

Writing Equations Showing Dissociation

Ionic compounds will give ions when dissolved in water.

E.g., magnesium fluoride:

$$MgF_{2(s)} \rightarrow Mg^{2+}_{(aq)} + 2F^{-}_{(aq)}$$

Interpreting the equation:

1) One mol of magnesium fluoride gives one mol of magnesium ion and two mols of fluoride ions, hence the use of 2 in front of fluoride ion as coefficient ($2F^-$). Don't leave the 2 as a subscript (~~F_2^-~~).

2) Always write the products as ions with the proper valencies (charges) – strontium is group two hence 2+.

$$Sr_3(PO_4)_{2\,(s)} \rightarrow 3Sr^{2+}_{(aq)} + 2PO_4^{3-}{}_{(aq)}$$

In cases of polyatomic ions, they are written as polyatomic **ions**, unless you see the products differently. If there is parenthesis then remove the parenthesis and use the subscript outside as the coefficient in the product/ions.

Dissociation of Acids and Bases

ACIDS

- Acids look like they are covalent compounds, however they are always made in water, so they exist as an aqueous solution. In water acids will dissociate to give H^+ ions and the anions.

$$HCl_{(aq)} \rightarrow H^+_{(aq)} + Cl^-_{(aq)}$$

$$H_2SO_{4\,(aq)} \rightarrow 2H^+_{(aq)} + SO_4^{2-}{}_{(aq)}$$

- One H^+ in solution means the acid is monoprotic, when 2 protons are formed, as in sulfuric acid, that is a diprotic acid.

BASES

- In case of bases, there will generally be OH^-, hydroxide ion, in the solution.

Metal base: $Al(OH)_{3\,(s)} \rightarrow Al^{3+}_{(aq)} + 3OH^-_{(aq)}$

Nonmetallic base: $NH_{3(g)} + H_2O_{(l)} \rightleftharpoons NH_4^+{}_{(aq)} + OH^-_{(aq)}$

The equation arrow in the case of ammonia indicates that it is in equilibrium, going forwarded and backward during the reaction.

Strong Acids and Bases

Strong acids and bases will dissociate completely.

Strong bases are the hydroxides of metals, e.g. NaOH, KOH, $Ca(OH)_2$, $Al(OH)_3$. Strong acids and their ions are given in the table below.

ACID	DISSOCIATION EQUATION
Hydrochloric acid	$HCl_{(aq)} \longrightarrow H^+_{(aq)} + Cl^-_{(aq)}$
Hydrobromic acid	$HBr_{(aq)} \longrightarrow H^+_{(aq)} + Br^-_{(aq)}$
Nitric acid	$HNO_{3(aq)} \longrightarrow H^+_{(aq)} + NO_3{}^-_{(aq)}$
Chloric acid	$HClO_{3(aq)} \longrightarrow H^+_{(aq)} + ClO_3{}^-_{(aq)}$
Sulfuric acid	$H_2SO_{4(aq)} \longrightarrow 2H^+_{(aq)} + SO_4{}^{2-}_{(aq)}$

Solved Problem: Writing dissociation equations

For the compounds given below:

a) Predict if there will be dissociation. C_2H_5OH, $Ba(NO_3)_2$, CH_3CH_3, H_2O, $CuSO_4$.

b) Write the dissociation equation in aqueous solution.

a) Dissociation prediction

C_2H_5OH	no, covalent molecule will not dissociate.
$Ba(NO_3)_2$	yes, ionic compound will give ions in water
CH_3CH_3	no, covalent molecule will not dissociate.
H_2O	no, covalent molecule will not dissociate.
$CuSO_4$	yes, ionic compound will give ions in water

b) Dissociation equations:

$$Ba(NO_3)_{2\,(s)} \rightarrow Ba^{2+}_{(aq)} + 2NO_3^-{}_{(aq)}$$

$$CuSO_{4\,(s)} \rightarrow Cu^{2+}_{(aq)} + SO_4^{2-}{}_{(aq)}$$

Electrolytes

Electrolyte: An electrolyte is a substance that conducts electricity in aqueous solution. This solution will contain ions.

There are three types of electrolytes:

Strong Electrolyte: These substances dissolve completely in water have 100% dissociation.

- All water soluble ionic compounds, strong acids and strong bases.

Weak Electrolytes: These substances dissolve partially or dissociate partially in water. This solution does not contain many ions.

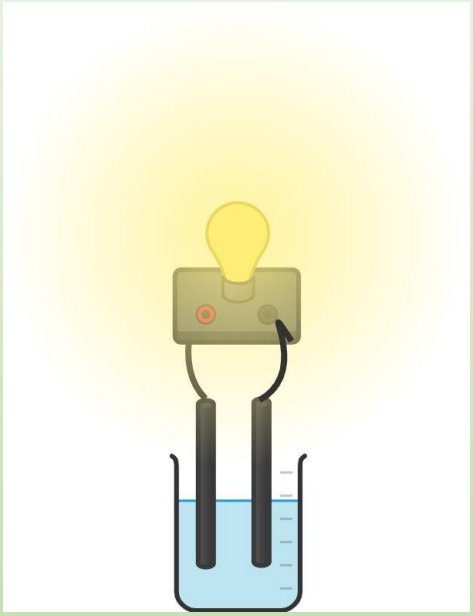
- Exist mostly as the molecular form in solution.
- Weak acids (acetic acid) and weak bases (ammonia).

Nonelectrolyte: These substances dissolved in water produces a solution that does not conduct electricity and does not contain ions.

- Covalent compounds will fall in this category.

Electrolytes

The best way distinguish between electrolytes is to see if they conduct electricity and with how much intensity a bulb would light up.

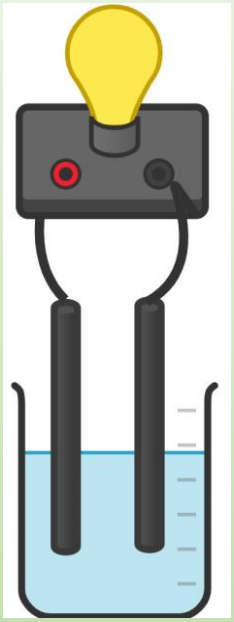


Strong electrolyte

Strong conduction of electricity. E.g., strong acid solutions(HCl), salt (NaCl) solution

Weak electrolyte

Weak conduction of electricity. E.g., tap water, acetic acid ($HC_2H_3O_2$).



Nonelectrolyte

No conduction of electricity. E.g., distilled water, ethanol (C_2H_5OH), sugar solution

Electrolytes – Practical Application

Our body has about 70% water and has a number of ions in our body; some common ions are Na^+, Ca^{2+}, K^+, Cl^-, CO_3^{2-}.

Electrolytes help with nerve impulses in our nervous system and help with muscle contractions by maintaining a certain voltage in our cells.

We ingest electrolytes through solid and liquid foods and the kidneys maintain the electrolytic balance in the body. If the ions are not in the correct concentration, then our body functions cannot occur.

We lose electrolytes in two different ways: a) we lose water in the body, so the concentration of ions change and b) we lose ions during sweating. We can lose muscle control if ions are not replenished.

The best way to replenish our ions is by drinking electrolytes, most commonly found in sports drinks. But we have to be careful though – they can have a lot of sugar in them!

The first electrolyte beverage was invented in University of Florida……

Solved Problem: Predicting electrolyte strengths

Predict if the following compounds will be strong, weak or non-electrolytes in water. Give a brief explanation for your answer.

HBr, KCl, HI, H_2, KOH, NH_4I, HCOOH.

HBr – strong electrolyte because it is a strong acid.
KCl – strong electrolyte because it is an ionic compound.
HI – strong electrolyte because it is a strong acid.
H_2 – nonelectrolyte because it is a covalent compound.
KOH – strong electrolyte because it is a strong base.
NH_4I – strong electrolyte because it is an ionic compound.
HCOOH – weak electrolyte because it is a weak acid.

Key Words and Concepts

- **Ions in Aqueous Solution**
  - Electrolytes
  - Strong, Weak and Non
  - Acids and Bases as electrolytes