General Properties of Aqueous Solutions

Advanced Chemistry
Introduction

- Aqueous solution: a solution in which water is the dissolving medium
- In this chapter we will examine chemical reactions that take place in aqueous solutions.
- We will also be building on concepts of stoichiometry
Solutions

- Solution: homogenous mixture of two or more substances
- Solvent: substance present in the greatest quantity and dissolves the other substance
- Solutes: dissolved in the solvent
- Ex: When a small amount of sodium chloride (NaCl) is dissolved in a large quantity of water - water is the solvent and sodium chloride is the solute.
Electrolytic Properties Introduction

- At a young age we learn not to bring electrical devices into the bathtub so we do not electrocute ourselves.
- However, pure water is a poor conductor of electricity. So what makes bathwater so conductive?
- The conductivity of bathwater originates from the substances dissolved in the water, not the water itself.
Electrolytic Properties Introduction

- Not all substances that dissolve in water results in a conductive solution
- Dissolving Salt vs Table sugar has very different electrical conductivities
- Salt solution is a good conductor of electricity; sugar solution is not
Electrolytic Properties

- On a conductivity meter, the bulb lights up only if there is a current (flow of electrical particles) between two electrodes immersed in solution.
  - Conductivity occurs when ions are present in solution because the ions carry electrical charges.
- Electrolyte: substance whose aqueous solutions carry ions; such as NaCl
- Nonelectrolyte: substance that does not form ions in solutions; such as sugar
When an ionic substance dissolves in water, the solvent pulls the individual ions from the crystal and solvates (surrounds) them.

This process is called dissociation.

Ions are “solvated”.

Dissociation
Ionic Compounds in Water

- NaCl consists of Na+ and Cl- ions. When NaCl dissolves in water, each ion separates and disperses throughout the solution.
- The ionic solid dissociates into the component ions as it dissolves.
Ionic Compounds in Water

- Water is a very effective solvent for ionic compounds. Although H$_2$O is an electrically neutral molecule, the O atom is rich in electrons and has a partial negative charge and each H atom has a partially positive charge.

- Cations (positive ions) are attracted by the negative end on H$_2$O, and anions (negative ions) are attracted to the positive end.
Ionic Compounds in Water

- As ionic compounds dissolve, the ions become surrounded by H2O molecules. The ions are said to be solvated.
  - In chemical equations, we denote solvated ions by writing them as Na+ (aq) and Cl- (aq), where aq is an abbreviation for aqueous.
- Solvation helps stabilize the ions in solution and prevent cations and anions from recombining.
Ionic Compounds in Water

- We can predict the nature of ions in a solution of an ionic compound from the chemical name of the substance. Sodium sulfate $\text{Na}_2\text{SO}_4$ for example dissociates into sodium ions ($\text{Na}^+$) and sulfate ions ($\text{SO}_4^{2-}$)

- What dissolved ions are present in a solution of
  - KCN
  - NaClO$_4$
Molecular Compounds in Water

- When a molecular compound dissolves in water, the solution usually consists of intact molecules dispersed throughout the solution.
- Consequently, most molecular compounds are nonelectrolytes.
- A few molecular substances have aqueous solutions that contain ions. Acids are the most important of these solutions.
- For example, HCl dissolves in water to form hydrochloric acid, HCl (aq), it ionizes’ that is, it dissolves into H+(aq) and Cl- (aq) ions.
Strong and Weak Electrolytes

- Electrolytes differ in the extent to which they conduct electricity.
- Strong electrolytes: solutes that exist in solution completely or nearly completely as ions.
  - Water soluble ionic compounds (NaCl) and few molecular (HCl)
- Weak electrolytes: solutes that exist in solution mostly in the form of neutral molecules with only a small fraction in the form on ions.
  - Acetic acid (CH₃COOH) - most of the solute is present as CH₃COOH (aq) molecules. Only small fraction dissociates into H⁺(aq) and CH₃COO⁻(aq) ions.

**TABLE 4.3 • Summary of the Electrolytic Behavior of Common Soluble Ionic and Molecular Compounds**

<table>
<thead>
<tr>
<th></th>
<th>Strong Electrolyte</th>
<th>Weak Electrolyte</th>
<th>Nonelectrolyte</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Ionic</strong></td>
<td>All</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td><strong>Molecular</strong></td>
<td>Strong acids (see Table 4.2)</td>
<td>Weak acids, weak bases</td>
<td>All other compounds</td>
</tr>
</tbody>
</table>

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Strong Electrolytes Are...

- Strong acids
- Strong bases
- Soluble ionic salts

**TABLE 4.2 • Common Strong Acids and Bases**

<table>
<thead>
<tr>
<th>Strong Acids</th>
<th>Strong Bases</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydrochloric, HCl</td>
<td>Group 1A metal hydroxides [LiOH, NaOH, KOH, RbOH, CsOH]</td>
</tr>
<tr>
<td>Hydrobromic, HBr</td>
<td>Heavy group 2A metal hydroxides [Ca(OH)_2, Sr(OH)_2, Ba(OH)_2]</td>
</tr>
<tr>
<td>Hydroiodic, HI</td>
<td></td>
</tr>
<tr>
<td>Chloric, HClO_3</td>
<td></td>
</tr>
<tr>
<td>Perchloric, HClO_4</td>
<td></td>
</tr>
<tr>
<td>Nitric, HNO_3</td>
<td></td>
</tr>
<tr>
<td>Sulfuric, H_2SO_4</td>
<td></td>
</tr>
</tbody>
</table>

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Strong and Weak Electrolyte Misconception

- We must not confuse solubility level with electrolyte strength.
  - For example, acetic acid $\text{CH}_3\text{COOH}$ is extremely soluble in water but is a weak electrolyte.
  - $\text{Ca(OH)}_2$, is not very soluble in water, but the amount that does dissolve dissociates almost completely making it a strong electrolyte.
Identifying Strong and Weak Electrolytes

- If we remember the common strong acids and bases and also remember that NH$_3$ is a weak base, we can make reasonable predictions about the electrolytic strength of water soluble substances.

- To classify a soluble substance as a strong electrolyte, weak electrolyte or nonelectrolyte.
  - Is the substance ionic or molecular.
    - If it is ionic, it is a strong electrolyte.
    - If molecular, we ask whether it is an acid or base.
      - If not an acid of base, it is a nonelectrolyte.
  - Determine if acid or base is a strong acid or base
    - Strong acid or base = strong electrolyte
    - Weak acid of base = weak electrolyte
Identifying Strong, Weak, and Nonelectrolytes

- Classify the following dissolved substances as strong, weak, or nonelectrolyte.
  - CaCl$_2$
  - HNO$_3$
  - C$_2$H$_5$OH (ethanol) *hint not a base
  - HCOOH (formic acid)
  - KOH
How can you test if a solution is an electrolyte? Strong or weak?

- Dissolve substances in water.
- Connect a battery and light bulb.
- Put the wires in the solution.
- If the bulb lights, then it’s electrolytic.
- The brighter the bulb, the more current, so the stronger the electrolyte.