Solutions

A solution is a homogeneous mixture of two or more substances in a single physical state. A solution contains two parts:

The solvent is the component that dissolves the other materials into it and is usually in larger amount

The solute is the component(s) that dissolves into the solvent, usually in smaller amount.

Electrolytes

Some substances when dissolved in water will conduct electricity while others won't.

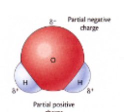
Electrolyte - an aqueous solution containing ions that conducts electricity

Nonelectrolyte - an aqueous solution in which the solute does not form ions.

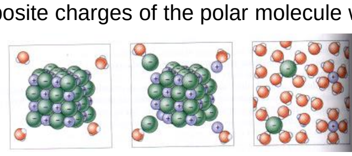
Electrolytic solutions are caused by ionic solids that dissociate (dissolve into ions) in water.

Dissolving

Water is not an ionic compound. However, it does have partial positive and negative sides to the molecules. A water molecule is called polar.



When water dissolves an ionic compound, the solid is taken apart into ions by the water molecules. The ions are attracted to the opposite charges of the polar molecule water



Strong & Weak Electrolytes

Strong electrolytes (ionic compounds) completely dissociate in water.

Ex. HCl (aq) --> H^+ (aq) + Cl^- (aq)

Weak electrolytes are molecular compounds that produce a small concentration of ions in solution

Ex. $HC_2H_3O_2$ (aq) <==> H^+ (aq) + $C_2H_3O_2^-$ (aq)

Being a strong or weak electrolyte does not mean that it dissolves a lot or a little. Some strong electrolytes only dissolve a little.

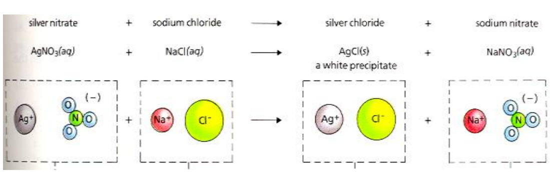
Molecular Substances

When a molecular substance dissolves, the structure of the molecule remains intact (no separation into ions).

However (as we'll see later), some molecular compounds will interact with the water to form ions.

Types of Reactions

Double Replacement or Metathesis - Atoms or ions from two different compounds replace each other.



Net Ionic Equations

When two solutions are mixed and a solid (precipitate) forms, it is called a precipitation reaction.

There are a few solubility rules that are useful in predicting what is the solid in a precipitation.

To show this precipitation, two types of equations are used:

Complete Equation: (Shows all aqueous + solids)

$Pb(NO_3)_2$ (aq) + 2 KI (aq) --> PbI_2 (s) + 2 KNO_3 (aq)

Net Ionic Equation: (Ignores ions that stay in solution)

Pb^{+2} (aq) + 2 I^- (aq) --> PbI_2 (s)

Acids

Acids are substances that ionize in aqueous solutions to produce H^+ ion.

Monoprotic acids are 1 H acids. (HCl)

Diprotic acids are 2 H acids. (H_2SO_4)

Diprotic acids can dissolve twice:

H_2SO_4 (aq) --> H^+ (aq) + HSO_4^- (aq) and

HSO_4^- (aq) --> H^+ (aq) + SO_4^{-2} (aq)

Bases

Bases are substances that accept H^+ ions in water. OH^- ions easily accept H^+ ions to form water.

NaOH (aq) --> Na^+ (aq) + OH^- (aq)

Not all bases have to end with OH^- to be a base:

NH_3 (aq) + H_2O (l) --> NH_4^+ (aq) + OH^- (aq)

Strong & Weak Acids & Bases

Strong acids and bases completely dissociate in water (strong electrolyte)

Weak acids and bases partially dissociate in water (weak electrolyte)

Neutralization

When an acid and bases are added together in stoichiometric proportions, the products are salt and water

$3\ NaOH_{(s)} + H_3PO_{4(aq)} \rightarrow 3\ H_2O_{(l)} + Na_3PO_{4(aq)}$

base acid water salt

The net ionic equation for this reaction is:

$3\ NaOH_{(s)} + 3\ H^+_{(aq)} \rightarrow 3\ H_2O_{(l)} + 3\ Na^+_{(aq)}$

Oxidation Reactions

When an element loses electrons due to a chemical reaction, the element undergoes oxidation

Ex. $2\ Ca_{(s)} + O_{2\ (g)} \rightarrow 2\ CaO_{(s)}$

This process is called oxidation because the first reactions of this type were discovered using oxygen.

Reduction Reactions

When an element gains electrons due to a chemical reaction, the element is said to undergo reduction.

Ex. 2 Ca $_{(s)}$ + O_2 $_{(g)}$ --> 2 CaO $_{(s)}$

When one substance loses electrons, another has to gain those electrons. Therefore, oxidation is always accompanied by reduction, which is called a redox reaction.

Oxidation Numbers

Since the number of electrons is not specifically given in formulas, it is sometimes necessary to work to determine the number of electrons on an atom.

The oxidation number is the actual charge of a monatomic ion; it can also be the theoretical charge of an individual atom within a polyatomic ion based on a set of rules.

Rules for oxidation numbers

- 1) An atom in its elemental form has a oxidation number of zero.
- 2) Alkali metals = +1. Alkali Earth metals = +2, Aluminum = +3
- 3) Oxygen: usually -2, except in peroxide (O_2^{-2}) where it is -1.
- 4) Hydrogen: +1 with a nonmetal, -1 with a metal

Rules for Oxidation Numbers

5) Halogens: -1 in a binary compound, when combined with oxygen in a polyatomic ion, the charge will be positive.

6) Sum of oxidation numbers: For a neutral compound is zero. The sum of oxidation numbers for a polyatomic ion is equal to its charge.

Redox Reactions

In a redox reaction, one element will get oxidized while another gets reduced.

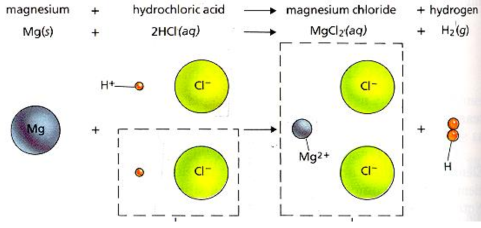
Ex. Mg (s)+ 2 HCl (aq) --> $MgCl_2$ (aq)+ H_2 (g)

In the above example, Mg gets oxidzed and H gets reduced. Cl is a spectator ion, so the net ionic equation is:

Mg (s)+ 2 H^+ (aq) --> Mg^{+2} (aq)+ H_2 (g)

Types of Reactions

Single Replacement - an uncombined element displaces an element that is part of a compound.



Concentrations

Chemists often need to specify precisely how concentrated or dilute a solution is. The concentration is the amount of solute in a given amount of solvent.

Molarity - the number of moles of solute dissolved in each liter of solution.

$$\text{Molarity (M)} = \frac{\text{moles solute}}{\text{liters solution}}$$

Dilutions

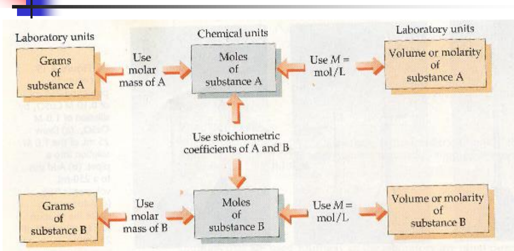
Adding water to lower the concentration of a material is known as dilution. When more solvent is added to a solution, the moles of solute remains the same.

Because of this fact, a simple relationship can be developed to allow us to dilute a solution:

Equation: $M_iV_i = M_fV_f$

Suppose you wanted to dilute a 3.00 M solution down to 250 mL of a 0.500 M solution. How much of the concentrated solution would you use?

Solutions & Stoichiometry



Solutions & Stoichiometry

Many times, instead of adding one solid to another in a chemical reaction, to make the reaction go faster we use aqueous solutions.

When this happens, many times we know the concentration and volume of the materials used. We can use this information to determine moles, and perform the mathematics of a simple stoichiometry problem.

Solution Stoichiometry

a) How many grams of H_2O (l) are produced when 25.0 mL of 0.150 M HNO_3 (aq) are completely neutralized by $Ca(OH)_2$ (aq)?

b) How many mL of the 0.250 M $Ca(OH)_2$ (aq) were used in this reaction?

c) What salt is produced by this reaction?

d) *What concentration of this salt is made by the neutralization?

Review Problems

1) Acetone, CH_3COCH_3 is a nonelectrolyte; hypochlorus acid, HClO is a weak electrolyte and ammonium chloride, NH_4Cl is a strong electrolyte.

a) What solute particles are present for each aqueous solution?

b) What do the dissociation reactions look like for each substance?

Titrations

When attempting to determine the concentration of a solution, we may use a standard solution, a second solution of known concentration, to react with the first. When we do this, we need to know exactly what volume of the standard solution we used to react with the unknown concentration. This type of procedure is called a titration.

Review Problems

2) Aqueous solutions of strontium hydroxide and ammonium sulfate are added together.

a) Write the reaction and predict the products.
b) Determine the precipitate.
c) Write a net ionic equation.

Review Problems

Solid iron (III) oxide can be treated by carbon monoxide gas to make solid iron and carbon dioxide gas.

a) Write a balanced equation for the reaction
b) Determine the oxidation numbers for all elements in the reaction.
c) Which element is oxidized? Which is reduced?

Review Problems

- Using the activity series (Table 4.5), predict the products of the following reactions:

a) Zn (s) + $CaCl_2$ (aq) -->

b) $AgNO_3$ (aq) + Na (s) -->

c) Co (s) + CrI_3 (aq) -->

d) Al (s) + HCl (aq) -->

- What is the molarity of a solution in which 30.0 g of K_2CO_3 is dissolved in 400 mL of water?
- What would the concentration of the solution be if 30 mL of the solution were diluted to 500 mL?