Focus

• Nature of ionic compounds in aqueous solution
• Types of chemical reactions:
  - Precipitation Reactions
  - Acid-Base (neutralization) Reactions
  - Gas-Forming Reactions

Properties of Ions In Aqueous Solutions

Solution =

What happens when ionic compounds dissolves in water?

Properties of Ions In Aqueous Solutions

\[ \text{NaCl(s)} + \text{H}_2\text{O(l)} \rightarrow \]

\[ \text{Cl}^- \text{ion} \quad \text{Na}^+ \text{ion} \]

\[ \text{NaCl} \]
Properties of Ions In Aqueous Solutions

How do we know ions are present in aqueous solutions?

ELECTROLYTES

Properties of Ions In Aqueous Solutions: Types of Electrolytes
Properties of Ions In Aqueous Solutions: Types of Electrolytes

Non Electrolytes

These are substances that don’t dissociate (ionize) when they dissolve.

Their solutions do not conduct electricity

Examples:
- Sugar (Sucrose) \( \text{C}_{12}\text{H}_{22}\text{O}_{11} \)
- Ethanol \( \text{C}_{2}\text{H}_{5}\text{OH} \)
- Acetone \( (\text{CH}_3)_{2}\text{CO} \)
- Ethylene glycol (antifreeze) \( \text{HOCH}_2\text{CH}_2\text{OH} \)
Non-electrolyte— Ethanol, C₂H₅OH

Properties of Ions In Aqueous Solutions: Solubility of Ionic Compounds in Water

Are all ionic compounds soluble in water?

How can we predict the solubility of an ionic compound?
Properties of Ions In Aqueous Solutions: Solubility of Ionic Compounds in Water

**Soluble compounds**

- CuO, CuCl₂, FeCO₃
- AgI, Ag₃PO₄, AgNO₃
- K₂CO₃, KI, KMnO₄
- BaSO₄, Ba(NO₃)₂, BaCO₃

Properties of Ions In Aqueous Solutions: Solubility of Ionic Compounds in Water

**Insoluble compounds**

Exercise

Which of the following compounds are expected to be soluble in water?

- CuO, CuCl₂, FeCO₃
- AgI, Ag₃PO₄, AgNO₃
- K₂CO₃, KI, KMnO₄
- BaSO₄, Ba(NO₃)₂, BaCO₃
WATER SOLUBILITY OF IONIC COMPOUNDS

Common minerals are often formed with anions that lead to insolubility:
- sulfide
- fluoride
- carbonate
- oxide

Azurite, a copper carbonate
Iron pyrite, a sulfide
Orpiment, arsenic sulfide

Precipitation Reactions

A Precipitation reaction, produces an insoluble product

Example:

\[ \text{AgNO}_3 (aq) + \text{KCl} (aq) \rightarrow \]

Note that the reaction involves an exchange of anions i.e.
Precipitation Reactions

Exercise:
Predict the products of the following reactions and suggest with reason, whether or not the reaction is a precipitation reaction

\[ \text{CuCl}_2 (aq) + \text{H}_2\text{S}(aq) \rightarrow \]
\[ \text{CaCl}_2 (aq) + \text{K}_2\text{CO}_3 (aq) \rightarrow \]
\[ \text{AgNO}_3 (aq) + \text{NaI (aq)} \rightarrow \]

Precipitation Reactions

Exercise:
In each of the following cases, does a precipitation reaction occur? When the solution of the two water soluble reactants are mixed
Also write a balanced chemical equation for the precipitation reaction

(a). Sodium carbonate is mixed with copper (II) chloride
(b). Potassium carbonate is mixed with sodium nitrate
(c). Nickel (III) chloride is mixed with potassium chloride

Precipitation Reactions

(a). Sodium carbonate is mixed with copper (II) chloride
\[ \text{Na}_2\text{CO}_3 (aq) + \text{CuCl}_2 (aq) \rightarrow \]
(b). Potassium carbonate is mixed with sodium nitrate
\[ \text{K}_2\text{CO}_3 (aq) + 2\text{NaNO}_3 (aq) \rightarrow \]
(c). Nickel (III) chloride is mixed with potassium chloride
\[ \text{NiCl}_2 (aq) + \text{KCl (aq)} \rightarrow \]
Net Ionic Equations

- Commonly used for chemical reactions in aqueous solutions
- They describe the actual chemical species that are involved in the reaction

Steps in writing Net Ionic Equations:

Step 1
Write a complete, balanced molecular equation (indicate the state of each substance, l, g or s)

\[ \text{Pb(NO}_3\text{)}_2(\text{aq}) + 2\text{KI(aq)} \rightarrow \text{PbI}_2(s) + 2\text{KNO}_3(\text{aq}) \]

They describe the actual chemical species that are involved in the reaction.

Step 2
Re-write all strong acids, strong soluble bases, and soluble salts as ions (pay attention to those substances labeled with (aq)).

\[ \text{Pb}^{2+}(\text{aq}) + 2\text{NO}_3^-(\text{aq}) + 2\text{K}^+(\text{aq}) + 2\text{I}^-(\text{aq}) \rightarrow \text{PbI}_2(s) + 2\text{K}^+(\text{aq}) + 2\text{NO}_3^-(\text{aq}) \]

Step 3
Identify ions which remains unchanged in the reaction (These are called SPECTATOR IONS). Cancel them out of the equation

\[ \text{Pb}^{2+}(\text{aq}) + 2\text{I}^-(\text{aq}) \rightarrow \text{PbI}_2(s) \]

Net ionic equation:

\[ \text{Pb}^{2+}(\text{aq}) + 2\text{I}^-(\text{aq}) \rightarrow \text{PbI}_2(s) \]

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ACIDS AND BASES

Acids and bases can change colors of dyes

Acids and bases neutralize the effect of each other
ACIDS: PROPERTIES

An acid is a substance that when dissolved in water increases the concentration of hydrogen ions, \( H^+ (aq) \) in water.

\[
\text{Acid} + \text{Water} \rightarrow H^+ (aq) + \text{Acid anion}
\]

Acids react with carbonates to produce gaseous \( \text{CO}_2 \) and salt.

Acids react with many metals to form hydrogen gas.

ACIDS: CLASSIFICATION

There are many ways to classify acids:

- Number of H atoms (Mono- or poly protic acids)
- Presence of oxygen atoms (Oxo-acids)
- Presence of halogen atoms (Hydrohalic Acids)
- Electrolytic strength (Weak or strong Acids)

*For now we’ll go with the electrolytic strength classification*

ACIDS: STRONG ACIDS

Strong acids are strong electrolytes (i.e. they dissociate completely in solution).

*Examples of strong acids:*
ACIDS: WEAK ACIDS

Weak acids are weak electrolytes (i.e. only a fraction of the molecules dissociate in solution)

Examples

ACIDS: ACIDIC OXIDES

Nonmetal oxides are called acidic oxides

BASES: PROPERTIES

A base is a substance that increases the concentration of hydroxide ion, OH⁻ (aq) when dissolved in pure water

Base + Water → Cation + OH⁻
BASES: CLASSIFICATION

Bases can be classified into two groups:

Example:

BASES: CLASSIFICATION

Other examples of strong bases:
LiOH, KOH

BASES: CLASSIFICATION

Only a fraction of a weak base dissociates in water

Amt dissolved
Amt. dissoc.
Amt undissoc.
BASES: Basic Oxides

Metal oxides are bases

Examples:

ACIDS AND BASES: REACTIONS

Acids react with bases to produce salt and water

Example:

The cation of a salt comes from the base and its anion from the acid

The net ionic reaction from a strong acid and a strong base is the production of water

GAS FORMING REACTIONS

1. Reaction of acids with metal carbonates and bicarbonates to produce CO₂

Examples:

2. Reaction of acids with some metals to produce Hydrogen gas
GAS FORMING REACTIONS

3. Reaction of metal sulfide with acids to produce hydrogen sulfide gas

4. Reaction of acids and metal sulfite to form sulfur dioxide gas

5. Reaction of ammonium salt to form ammonia gas

REACTION DRIVING FORCES

Reactions in which the reactants are converted largely to products are said to be PRODUCT-FAVORED

e.g. precipitation reaction, acid base reactions and gas forming reactions

Reactions in which only a little of the reactant is converted to product are said to be REACTANT FAVORED

NaCl(aq) + H₂O(l) → NaOH(aq) + HCl(aq)

REACTION DRIVING FORCES

What is it that drive reactions in aqueous solution towards formation of products?

Ans:

<table>
<thead>
<tr>
<th>Reaction type</th>
<th>Driving force</th>
</tr>
</thead>
<tbody>
<tr>
<td>Precipitation</td>
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<tr>
<td>Acid-Base</td>
<td></td>
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<tr>
<td>Gas-forming</td>
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<td>Redox</td>
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