Chapter 4: Phenomena

Phenomena: Many different reactions are known to occur. Scientists wondered if these reactions could be separated into groups based on their properties. Look at the reactions below and divide the reactions into groups of similar reactions. Be able to state what property(s) you used to group them.

Hint: It might be helpful to print the reactions out so that you can move them around.

a) \( H^+(aq) + OH^-(aq) \rightarrow H_2O(l) \)
b) \( NH_3(aq) + HCN(aq) \rightarrow NH_4CN(aq) \)
c) \( Fe^{3+}(aq) + e^- \rightarrow Fe^{2+}(aq) \)
d) \( HC_2H_3O_2(aq) + KOH(aq) \rightarrow KC_2H_3O_2(aq) + H_2O(l) \)
e) \( 3Ca^{2+}(aq) + 2PO_4^{3-}(aq) \rightarrow Ca_3(PO_4)_2(s) \)
f) \( HBr(aq) + LiOH(aq) \rightarrow LiBr(aq) + H_2O(l) \)
g) \( AgNO_3(aq) + NaCl(aq) \rightarrow AgCl(s) + NaNO_3(aq) \)
h) \( 2H_2O(l) + 2e^- \rightarrow H_2(g) + 2OH^-(aq) \)
i) \( Sr(NO_3)_2(aq) + 2NaOH(aq) \rightarrow Sr(OH)_2(s) + 2NaNO_3(aq) \)
j) \( Cu^{+}(aq) + e^- \rightarrow Cu(s) \)
k) \( H_2SO_3(aq) + H_2O(l) \rightarrow SO_4^{2-}(aq) + 4H^+(aq) + 2e^- \)

Chapter 4: Types of Chemical Reactions and Solution Stoichiometry

Electrolytes

- **Electrolyte**: A substance that, in solution, is present as ions.
  - Examples: Ionic solids that are soluble in water and acids.
  - Note: Electrolyte solutions conduct electricity.

- **Strong Electrolyte**: A substance that is fully ionized in solution.
- **Weak Electrolyte**: A substance that is only partially ionized in solution

- **Nonelectrolyte**: A substance that does not form ions in solution.
  - Example: Molecular compounds that are not acids.

**Big Idea:** Reactions can be broken down into subgroups. Three types of reactions are precipitation (a solid is formed from 2 aqueous solutions), acid/base (salt and \( H_2O \) are produced), and oxidation/reduction (e^- are transferred). Many reactions involve species that are in solution. **Molarity** (mol per liter) is used to describe the concentration of species in a solution.

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**Molarity and Dilutions**

- Chemical Formula or Equation
- Molarity
- Mol
- Molar Mass
- Gram
- Volume
- Molecules
- Atoms
- Molecules/Equivalence
Chapter 4: Types of Chemical Reactions and Solution Stoichiometry

Molarity and Dilutions

**Student Question**

If the molarity of a solution of calcium chloride is known. What would you have to do to the molarity of the calcium chloride solution to get the molarity of the chloride ions in solution?

a) It is the same  
b) Multiply the molarity by 2  
c) Divide the molarity by 2  
d) Multiply the molarity by 3  
e) Not enough information given

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Molarity and Dilutions

**Student Question**

A solution is prepared by dissolving 0.005736 mol of oxalic acid (C₂H₂O₄) to make 0.1000 L of solution. A 0.01000 L portion is then diluted to 0.2500 L. What is the molarity of the final solution?

a) 2.295×10⁻³ M  
b) 2.295 M  
c) 5.738×10⁻² M  
d) 5.737 M  
e) None of the above

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Molarity and Dilutions

**Calculating Amount of Stock Solution Needed**

- **Step 1:** Calculate the amount of solute, \( n \), needed in the final solution, \( V₂ \):
  \[ n = \left( \frac{M₂}{M₁} \right) V₂ \]

- **Step 2:** Calculate the volume, \( V₁ \), of the initial stock solution of molarity \( M₁ \) that contains \( n \) moles:
  \[ V₁ = \frac{n}{M₁} \]

**Note:** Since the amount of moles is the same in Step 1 and 2, the equations can be combined into one equation.

\[ V₂ = \frac{M₂ V₁}{M₁} \] or \[ M₁ V₁ = M₂ V₂ \]

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Precipitation Reactions

- **Precipitate:** The formation of a solid in a solution during a chemical reaction.

- **Soluble Substance:** A substance that dissolves to a significant extent in a specified solvent.
  
  **Note:** If no solvent is mentioned, the solvent is assumed to be water.

- **Insoluble Substance:** A substance that does not dissolve significantly in a specified substance.
  
  **Note:** A substance is considered insoluble if they do not dissolve to more than ~0.1 M.

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Precipitation Reactions

1. Most nitrate (NO₃⁻) salts are soluble.
2. Most salts of Na⁺, K⁺, and NH₄⁺ are soluble.
3. Most chlorides are soluble. Notable exceptions are AgCl, PbCl₂, and Hg₂Cl₂.
4. Most sulfate salts are soluble. Notable exceptions are BaSO₄, SrSO₄, PbSO₄, and CaSO₄.
5. Most hydroxide salts are only slightly soluble. The important soluble hydroxides are NaOH, KOH, and Ca(OH)₂ (marginally soluble).
6. Most sulfide (S²⁻), carbonate (CO₃²⁻), and phosphate (PO₄³⁻) salts are only slightly soluble.
Chapter 4: Types of Chemical Reactions and Solution Stoichiometry

Precipitation Reactions

Solubility Song
(Sung to the tune of 99 Bottles of Beer on the Wall)

Potassium, sodium, and ammonium salts, Whatever they may be,
Can always be depended on for solubility.
When asked about the nitrates The answer is always clear,
They each and all are soluble, is all we want to hear.

Most every chloride’s soluble At least we’ve always read
Except silver, mercurous mercury And (slightly) chloride of lead.

Rule 2: Most salts of Na+, K+, and NH4+ are soluble
Rule 1: Most nitrates (NO3-) salts are soluble
Rule 3: Most chlorides are soluble. Notable exceptions are AgCl, PbCl2, and Hg2Cl2

Precipitation Reactions

Student Question

How many of the following compounds are soluble in water?

- Ba3(PO4)2
- Ba(NO3)2
- K2CO3
- Cu(OH)2

a) 1
b) 2
c) 3
d) 4

Precipitation Reactions

Molecular Equation: Balanced chemical reaction.

Example: CoCl2(aq) + Ca(OH)2(aq) → Co(OH)2(s) + CaCl2(aq)

Complete Ionic Equation: A balanced equation expressed in terms of the cations and anions present.

Example: Co2+(aq) + 2Cl-(aq) + Ca2+(aq) + 2OH-(aq) → Co(OH)2(s) + Ca2+(aq) + 2Cl-(aq)

Net Ionic Equation: The equation showing the net change in a chemical reaction, obtained by canceling the spectator ions in a complete ionic equation.

Example: Co2+(aq) + 2OH-(aq) → Co(OH)2(s)

Spectator Ions: Ions that do not play a role in the chemical reaction.

Examples: Cu2+ and Cl-
Chapter 4: Types of Chemical Reactions and Solution Stoichiometry

Precipitation Reactions

- Does a reaction occur when the following substances are mixed? If so, write out the molecular equation, complete ionic equation, and net ionic equation, as well as identify the spectator ions.
  - NH₄Cl(aq) and H₂SO₄(aq)
  - K₂CO₃(aq) and SnCl₂(aq)

Student Question

What is the final concentration of OH⁻ ions in solution if 1 mol of CsNO₃ is mixed with 2 mol of NaOH and the final volume of solution is 1.0 L.

CsNO₃(aq) + NaOH(aq) → CsOH(s) + NaNO₃(aq)

a) 0 M  b) 0.5 M  c) 1.0 M  d) 2.0 M  e) None of the above

Applications of Precipitation Reactions

- **Make Compounds**: Choose starting solutions that form a precipitate of the desired insoluble compound when they are mixed.
- **Qualitative Analysis**: Determine substances present in a sample.
  
  **Note**: The formation of a precipitate is used to confirm the identity of certain ions.
- **Quantitative Analysis**: Determine the amount of each substance or element present.
  
  **Note**: This can be done by gravimetric analysis (the amount of substance present is determined by measurements of mass i.e. measure the amount of precipitate).

Acid Base Reactions

Arrhenius Acids and Bases

- **Acid**: A compound that forms hydrogen (H⁺) ions in water.
  - Example: HCl(aq) acid
  - OH⁻(aq) not an acid because it does not release (H⁺) ions in solution.

- **Base**: A compound that produces hydroxide (OH⁻) ions in water
  - Example: NaOH(aq) base
  - NH₃ base because NH₃(aq) + H₂O(l) → NH₄⁺(aq) + OH⁻(aq).

In this titration, HCl, analyte, is in the Erlenmeyer flask and NaOH, titrant, is in the burette. Phenolphthalein, which is clear in the presence of an acid and pink in the presence of a base, is added to the HCl. NaOH is added to the HCl until the solution turns pink, which signifies the equivalence point has been reached.
Acid Base Reactions

**Titration Calculations**
- **Step 1:** Write the equation.
- **Step 2:** Find the number of moles of titrant, or "known" substance needed to get to the equivalence point.
  - **Equivalence point:** The stage in a titration when exactly the right volume of solution needed to complete the reaction has been added.
- **Step 3:** Use the mole ratio to find the moles of analyte.
- **Step 4:** Turn moles into \( M \), mass\%, etc.

**Acid Base Reactions**

During a titration a 0.02500 L sample of \( H_2SO_4 \) required 24.16 mL of 0.106 M \( NaOH \) to reach the equivalence point. What is the initial concentration of the \( H_2SO_4 \)?

If 35 mL of 0.45 M \( HCl \)(aq) and 25 mL of 1.0 M \( NaOH \)(aq) are mixed together will the solution be acidic, basic, or neutral?

**Oxidation Reduction Reactions**

**Assigning Oxidation Number**
1. The oxidation number (ON) of an element uncombined with another element is zero: \( Na(s) \), \( H_2(g) \), \( I_2 \) ...
2. For monatomic ions, the charge is the ON: \( Na^+ \) ON = +1.
3. The ON’s of elements in group 1 equal 1 (ex. Lithium ON = +1) ON’s of elements in group 2 equal 2 (ex. Magnesium ON = +2).
4. The ON of fluorine is always -1 in compounds.
5. The ON of the other elements in group 7 usually equal -1.
6. The ON of oxygen is usually -2 in compounds. Exceptions are fluorine compounds and peroxide (a compound that contains an O-O single bond).
7. Hydrogen’s ON is +1 when combine with non metals and -1 when combined with metals.
8. The sum of the ON’s of all the atoms in a species is equal to its total charge.

**Oxidizing Agent:** A species that removes electrons from a species being oxidized in a redox reaction.
- **Note:** The oxidizing agent contains the species being reduced.

**Reducing Agent:** The species that supplies electrons to a substance being reduced in a redox reaction.
- **Note:** The reducing agent contains the species being oxidized.

**Student Question**

What is the oxidation number of chromium in the ionic compound \( Na_2Cr_2O_7 \)?

- a) 2
- b) 6
- c) 7
- d) 12
- e) None of the above
Chapter 4: Types of Chemical Reactions and Solution Stoichiometry

**Oxidation Reduction Reactions**

**Student Question**

Identify the oxidizing agent in the reaction:

\[ \text{Al}(s) + \text{Fe}_2\text{O}_3(s) \rightarrow \text{Fe}(s) + \text{Al}_2\text{O}_3(s) \]

a) \( \text{Al}(s) \)  
   b) \( \text{Fe}_2\text{O}_3(s) \)  
   c) \( \text{Fe}(s) \)  
   d) \( \text{Al}_2\text{O}_3(s) \)

**Balancing Simple Redox Reactions**

(no oxygen or hydrogen in the reaction)

- **Step 1:** Write unbalanced half reactions.
- **Step 2:** Balance half reactions (atoms and electrons).
- **Step 3:** Multiply half reactions by an integer so that number of electrons match, then add reactions together.

**Balancing Redox Reactions in Basic Conditions**

- **Step 1:** Balance the reaction as if it were in acidic conditions.
- **Step 2:** Determine the number of \( \text{H}^+ \) in the balanced equation.
- **Step 3:** Add the same number of \( \text{OH}^- \) as there are \( \text{H}^+ \) to both sides of the equation.
- **Step 4:** The \( \text{H}^+ \) and \( \text{OH}^- \) on one side of the reaction will combine and form \( \text{H}_2\text{O} \).
- **Step 5:** Simplify your reaction (combined waters) if necessary.

**Take Away From Chapter 4**

Big Idea: Reactions can be broken down into subgroups. Three types of reactions are (1) precipitation (a solid is formed from 2 aqueous solutions), (2) acid/base (salt and \( \text{H}_2\text{O} \) are produced), and (3) oxidation/reduction (e- are transferred). Many reactions involve species that are in solution. Molarity (mol per liter) is used to describe the concentration of species in a solution.

- **Electrolytes**
  - Be able to identify electrolytes (ionic compounds and acids) and nonelectrolytes (molecular compounds that are not acids).
- **Molarity and Dilutions**
  - Be able to calculate the molarity of a solution (13,21,26)
  - \[ M = \frac{n}{V} \]
  - Be able to determine the molarity of solutions after dilutions (27,28,30)
  - \[ M_{1}V_{1} = M_{2}V_{2} \]
Take Away From Chapter 4

**Precipitation Reactions**
- Know the solubility rules and be able to predict when a precipitate forms. (36,40,42)
- Be able to write the molecular, complete ionic, and net ionic equations for a reaction and identify the spectator ions. (39)
- Be able to apply stoichiometry to precipitation reactions. (44,45,49,53,55)

**Acid and Base Reactions**
- Know that when an acid and a base react they form water and a salt.
- Be able to use titration data to get the concentration of an acid or base. (61,64,66,67)
- Be able to apply stoichiometry to acid/base reactions. (71)

**Oxidation and Reduction Reactions**
- Be to assign oxidation numbers. (75,77)
- Be able to identify what is oxidized and what is reduced in a redox reaction (OIL RIG) as well as identify the oxidizing and reducing agents. (78)
- Be able to balance redox reactions in acid and base solutions. (81,82)
- Be able to apply stoichiometry to redox reactions. (85,86)