Aqueous Reactions and Solution Stoichiometry
Chapter 4, Sections 20.1 and 20.2

Lesson 1: Section 4.1
4.1 General Properties of Aqueous Solutions, page 122

- ________________ – homogeneous mixture
- ________________ – what gets dissolved
- ________________ – what does the dissolving
- ________________ – can be dissolved
- ________________ – liquids dissolved in each other

Aqueous Solutions –

- Water is a good solvent because
- This means that oxygen atoms have a ____
- The hydrogen atoms have a ____
- The bond angle is ______________.
- Draw a water molecule:

Solvation –

- This is known as _______________ when the solvent is water.
- Ions have charges and attract the ____________________ charges on the water molecules.
- Draw a sample salt being hydrated by water:

Solubility – ____

- This is usually measured in ____________________ units.
- Solubility varies greatly, but if they do dissolve the ions ________________________________,
- And they can _______________________.
- The ionic solid ___________ into its component ions as it dissolves.
- Water can also dissolve non-ionic compounds if they have ______________________________.

Electrolytes

Electricity is _________________________.

- The ions that are dissolved can move.
- Solutions of ___________________ can conduct electricity and are called ____________________.
- Solutions Can be classified 3 ways:
    - Strong electrolytes –
        -
    - Weak electrolytes –
        -
    - Nonelectrolytes –
        -

Molecular Compounds in water usually consist of intact molecules dispersed throughout the solution. Consequently, most molecular compounds are ______________________.

- There are, however, a few molecular substances whose aqueous solutions contain ions. The most important of these are _______________.

Acidic Solutions

Acids form ___________________ when dissolved.

Strong acids _____________________ completely

There are 7 strong acids you need to memorize:

-
-
-
-
-
-
-

Now you know all the weak ones, as well.

Write the dissociation equation for hydrochloric acid:

Write the dissociation equation for acetic acid:

- Give it some thought:
  - What dissolved species are present in a solution of:
    - KCN?
    - $NaClO_4$?
  - Write the dissociation equation for ammonium phosphate:
  - Which solute will cause a light bulb to glow more brightly, CH_3OH or $MgBr_2$? Why?
  - Draw a diagram representing aqueous solutions of each of the following ionic compounds. Make each drawing contain 6 cations and the appropriate number of anions. Make the charge of the ion relative to its size.

Nickel II Sulfate	Calcium Nitrate	Sodium Phosphate	Aluminum Sulfate

Lesson 2

4.2 Precipitation Reactions

- When aqueous solutions of poured together, a ________________ forms.
- A solid that forms from solutions is called a __________________.
- "If you are not part of the ____________, you are part of the _____________."
- Follow this demonstration:
  - React aqueous solutions of sodium hydroxide and iron (III) chloride, including all adjectives.
  - Now, rewrite in ionic form, including all adjectives.
  - Get rid of the spectator ions and show all that really happens:
- Precipitation reaction (Called ____________________________)
  - We can predict the __________________.
  - Can only be certain by __________________.
  - The __________ and ____________ switch partners.
- You Try It: Write equations for the three reactions below:
  - $AgNO_3(aq) + KCl(aq) \rightarrow$
  - $Zn(NO_3)_2(aq) + BaCr_2O_7(aq) \rightarrow$
  - $CdCl_2(aq) + Na_2S(aq) \rightarrow$
- Precipitations Reactions
  - Only happen if one of the products is ________________________.
  - Otherwise all the ions stay _______________– nothing has happened.
  - **Need to memorize the rules for solubility (pg 127)**

- **<u>Solubility Rules</u>**
  - <u>Soluble Ionic Compounds</u>
    1. All nitrates are soluble
    2. All acetates are soluble
    3. Alkali metals ions and NH_4^+ ions are soluble
    4. Halides are soluble except Ag^+, Pb^{+2}, and Hg_2^{+2}
    5. Most sulfates are soluble, except Pb^{+2}, Ba^{+2}, Hg_2^{+2}, and Sr^{+2}
  - <u>Insoluble Ionic Compounds</u>
    6. Sulfides are insoluble except NH_4+, the alkali metal cations, and Ca2+ , Sr2+ and Ba2+ .
    7. Carbonates are insoluble except for NH_4+, and the alkali metal cations.
    8. Phosphates are insoluble except for ammonium and the alkali metal cations.
    9. Hydroxides are insoluble except the alkali metal cations, and NH_4+, Ca2+ , Sr2+ and Ba2+ .

- Three Types of Equations
  - ____________________– written as whole formulas, not the ions.
    - $K_2CrO_4(aq) + Ba(NO_3)_2(aq) \rightarrow$
  - ____________________________– show dissolved electrolytes as the ions.
    - $2K^+ + CrO_4^{-2} + Ba^{+2} + 2\ NO_3^- \rightarrow$
    - ___________________ are those that don't react.
  - __________________ show only those ions that react, not the spectator ions.
    - $Ba^{+2} + CrO_4^{-2} \rightarrow$

- Now You Try It:
  - Write the three types of equations for the reactions when these solutions are mixed.
    - iron (III) sulfate and potassium sulfide
    - Lead (II) nitrate and sulfuric acid.

Lesson 3 Section 4.3

4.3 Acid-Base Reactions

- For our purposes an acid is a ______________________.
- A base is a ___________________, usually _____________.
- What is the net ionic equation for the reaction of hydrochloric acid with potassium hydroxide?

Representing the Hydrogen Ion in water

- Just as ___________ are surrounded and bound by water molecules, the proton is also solvated by water molecules.
- You will see this represented 2 ways:
  - ______________
  - _____________called the _______________ ion
    - This is the correct way, but both are acceptable.

Mono, Di, TriProtic Acids

- Molecules of different acids can __________ and form different numbers of H^+ ions in water.
- Both HCl and HNO_3 are _____________ acids, which yield one H^+ per molecule of acid.
- Sulfuric acid, H_2SO_4, is a ____________ acid, one that yields two H^+ per molecule of acid.
- Phosphoric acid is a ______________acid, H_3PO_4
- Step-wise Ionization
  - The ionization of sulfuric acid occurs in two steps:
    - 100% Ionization because sulfuric acid is a **STRONG** acid.
    - Weak acid, so equilibrium is shown.

Bases

- Bases are substances that accept ________________________.
- Bases produce ________________ ions when they dissolve in water.
- Ionic hydroxide compounds such as ______________________________ are among the most common bases.
- Compounds that do not contain OH^- can also be bases.
- For example, ammonia (NH_3) is a common base.
- $NH_{3(aq)} + H_2O_{(l)} \rightarrow$

Because only a small fraction of the ammonia forms ammonium ion, ammonia is a weak electrolyte.

Strong and Weak Acids and Bases

–Acids and bases that are strong electrolytes, completely ionize in water, are called ______________________________

–Those that are weak electrolytes, partly ionize in water, are called ___________________________________

–Strong acids are more reactive than weak acids when the reactivity depends only on the concentration of _______________.

–The reactivity of an acid, however, can depend on the ______________ as well as on the H+ ion.

–___________is a weak acid, but it is very reactive and vigorously attacks many substances, including glass.

Common Strong Acids

–Strong Acids - MEMORIZE

1.
2.
3.
4.
5.
6.
7.

Common Strong Bases

–Strong Bases – MEMORIZE

1.

2.

Summary of the Electrolytic Behavior of Common Soluble Ionic and Molecular Compounds

	Strong Electrolyte	Weak Electrolyte	Nonelectrolyte
Ionic Compounds			
Molecular Compounds			

You Try It…

–Classify each of the following dissolved substances as a strong electrolyte, weak electrolyte or nonelectrolyte.

–Calcium chloride

–Nitric Acid

–Ethanol (C_2H_5OH)

–Formic Acid ($HCHO_2$)

–Potassium Hydroxide

Your Try It…

–Consider solutions in which 0.1 mole of each of the following compounds is dissolved in 1 L of water: Calcium nitrate, glucose, sodium acetate, and acetic acid. Rank the solutions in order of increasing electrical conductivity, based on the fact that the greater the number of ions in solution, the greater the conductivity.
Answer:

Neutralization Reactions and Salts

–Acids and Bases have different ____________________.

- Acids taste __________(lemons), bases taste _____________ (soap).
- Acids change the colors of certain dyes in a specific way different from that of bases. (indicators)

–Lots more coming in later chapters!

Neutralization

—Acid + Base → Salt + Water

—$HCl(aq) + NaOH(aq) \rightarrow$

—Water acts as the driving force.

—$H^+ (aq) + OH^- (aq) \rightarrow$

Demonstration

—Write the molecular, complete ionic, and net ionic equation for the following demonstration:

—Milk of Magnesia (Magnesium Hydroxide) reaction with Gastric Juice (Hydrochloric Acid)

—Molecular Equation:

—Net Ionic Equation:

You Try It…

—Write the Molecular Equation and Net Ionic Equation for the following neutralization reaction:

Acetic Acid + Barium Hydroxide

—Molecular Equation:

—Net Ionic Equation:

Acid-Base with Gas Formation

● There are many bases besides ________________ that react with acids to form molecular compounds.

● Two of these that you must know are the ____________ ion, S^{-2}, and the ____________ ion, CO_3^{-2}.

–Hydrogen sulfide gas smells like ________________.

–Carbonates and bicarbonates give off _____________ gas.

You Try It…

—Write the molecular and net ionic equations for:

—1. Hydrochloric acid + Sodium sulfide

—2. Hydrochloric acid + Sodium Bicarbonate

One more try…

—By analogy to examples already given in the lecture, predict what gas forms when sodium sulfite is treated with hydrochloric acid.

—Molecular Equation:

—Net Ionic Equation:

??Why aren't hydrogen sulfide and hydrogen sulfite named as acids in these examples?

Lesson 4 Sections 4.4, 20.1 & 20.2

4.4 Oxidation and Reduction Reactions

Commonly called ________________________

—Ionic compounds are formed through the transfer of ____________________.

—An Oxidation-reduction reaction involves the transfer of __________________.

We need a way of keeping track.

–Oxidation States

A way of keeping track of the electrons.
Not necessarily true of what is in nature, but it works.
need the rules for assigning (**memorize**).

1 The oxidation state of elements in their elemental form (standard state) is zero.

2 Oxidation state for monoatomic ions are the same as their charge.
Oxidation states

3 Oxygen is assigned an oxidation state of −2 in its covalent compounds except as a peroxide, then it is a −1. Na_2O_2, H_2O_2.

4 Hydrogen is +1 when bonded to nonmetals and −1 when bonded to metals.

5 In its compounds fluorine is always −1.

6 The sum of the oxidation numbers of all atoms in a neutral compound is zero. The sum of the oxidation numbers in a polyatomic ion equals the charge of the ion.

You Try It…

–Assign the oxidation states to each element in the following.

–CO_2

–NO_3^-

–H_2SO_4

–Fe_2O_3

–Fe_3O_4

You Try It…

–What noble gas element has the same number of electrons as the fluoride ion?________

–What is the oxidation number of that species?__________

You Try It…

–Determine the oxidation number of sulfur in each of the following:

- –Hydrogen sulfide
- –Elemental sulfur, S_8
- –Sulfur dichloride
- –Sodium sulfite
- –Sulfate ion

Oxidation-Reduction Reactions

–Transfer electrons, so the oxidation states change.

–$Na + 2Cl_2 \rightarrow$

–$CH_4 + 2O_2 \rightarrow$

–Oxidation is the ____________ of electrons.

–Reduction is the ______________ of electrons.

–OIL RIG

–LEO GER

–Oxidation means an _________ in oxidation state - lose electrons.

–Reduction means a ______________ in oxidation state - gain electrons.

–The substance that is oxidized is called the _____________ agent.

–The substance that is reduced is called the _________________ agent.

–Oxidizing agent gets ___________________.

Gains electrons.

More negative oxidation state.

–Reducing agent gets ___________________.

Loses electrons.

More positive oxidation state.

Identify the Oxidizing agent, Reducing agent, Substance oxidized, Substance reduced in the following reactions:

- $Fe\,(s) + O_2(g) \rightarrow Fe_2O_3(s)$

- $Fe_2O_3(s) + 3\,CO(g) \rightarrow 2\,Fe(l) + 3\,CO_2(g)$

- $SO_3^- + H^+ + MnO_4^- \rightarrow SO_4^- + H_2O + Mn^{+2}$

Oxidation of Metals by Acids

- Metals undergo ______________________ reactions with acids.

  Example: Magnesium metal reaction with hydrochloric acid

  •Label the substances that were oxidized and reduced.

  •Label the substances that are the oxidizing and reducing agents.

  •Write the net ionic equation.

•Oxidation of Metals by Salts

- Metals can also be oxidized by aqueous solutions of various salts.
  Example: Iron metal reacts with a solution of Nickel (II) nitrate.
  •Label the substances that were oxidized and reduced.
  •Label the substances that are the oxidizing and reducing agents.
  •Write the net ionic equation.

The Activity Series

- A list of metals arranged in order of _______________ ease of oxidation.
- Any metal on the list can be oxidized by the ions of elements __________ it.

You try it…

–Will an aqueous solution of iron (II) chloride oxidize magnesium metal? If so, write the balanced molecular and net ionic equations for this reaction.
Answer:

You Try It…

- Which of the following metals will be oxidized by $Pb(NO_3)_2$?

–Zn, Cu, Fe
Answer:

Half-Reactions

- All redox reactions can be thought of as happening in two halves.
- One _________________electrons - Oxidation half.
- The other _______________electrons - Reduction half.
- Write the half reactions for the following.
- $Na + Cl_2 \rightarrow Na^+ + Cl^-$

- $SO_3^- + H^+ + MnO_4^- \rightarrow SO_4^- + H_2O + Mn^{+2}$

Balancing Redox Equations

- In aqueous solutions the key is the number of _____________ produced must be the same as those required.
- For reactions in ________________ solution an 8 step procedure.

1 Write separate half reactions

2 For each half reaction balance all reactants except H and O

3 Balance O using H_2O

4 Balance H using H^+

5 Balance charge using e^-

6 Multiply equations to make electrons equal

7 Add equations and cancel identical species

8 Check that charges and elements are balanced.

Practice:

The following reactions occur in acidic aqueous solution. Balance them

- $Cr(OH)_3 + OCl^- + OH^- \rightarrow CrO_4^{-2} + Cl^- + H_2O$

- $MnO_4^- + Fe^{+2} \rightarrow Mn^{+2} + Fe^{+3}$

- $Cu + NO_3^- \rightarrow Cu^{+2} + NO(g)$

- $Pb + PbO_2 + SO_4^{-2} \rightarrow PbSO_4$

- $Mn^{+2} + NaBiO_3 \rightarrow Bi^{+3} + MnO_4^-$

Basic Solutions

- Do everything you would with acid, but add one more step.
- Add enough OH− to both sides to neutralize the H+
- $CrI_3 + Cl_2 \rightarrow CrO_4^- + IO_4^- + Cl^-$

- $Fe(OH)_2 + H_2O_2 \rightarrow Fe(OH)^-$

Lesson 5

4.5 Concentrations of Solutions

●Concentration- ____________________

●Review: Concentrated Vs. Dilute______________________________

●Review: Strong Vs. Weak _____________________________________

●Molarity =

abbreviated M

●1 M = 1 mol solute / 1 liter solution

Practice:

1. Calculate the molarity of a solution with 34.6 g of NaCl dissolved in 125 mL of solution.

2. How many grams of HCl would be required to make 50.0 mL of a 2.7 M solution?

3. What would the concentration be if you used 27g of $CaCl_2$ to make 500. mL of solution?

   What is the concentration of each ion?

4. Calculate the concentration of a solution made by dissolving 45.6 g of $Fe_2(SO_4)_3$ to 475 mL.

   What is the concentration of each ion?

Making solutions

5. Describe how to make 100.0 mL of a 1.0 M $K_2Cr_2O_4$ solution.

6. Describe how to make 250. mL of an 2.0 M copper (II) sulfate dihydrate solution.

Dilution –

- The moles of solute ________________.
- moles = M x L
- $M_1 V_1 = M_2 V_2$
- moles = moles
- ________________ is a solution of known concentration used to make more dilute solutions.

Practice:

7. What volume of a 1.7 M solutions is needed to make 250 mL of a 0.50 M solution?

8. 18.5 mL of 2.3 M HCl is added to 250 mL of water. What is the concentration of the solution?

9. 18.5 mL of 2.3 M HCl is diluted to 250 mL with water. What is the concentration of the solution?

10. You have a 4.0 M stock solution. Describe how to make 1.0L of a .75 M solution.

Lesson 6

4.6 Solution Stoichiometry and Chemical Analysis

●When we are working with solutions of known ______________, we use molarity and volume to determine the number of _____________________.

●How many grams of calcium hydroxide are needed to neutralize 25 mL of 0.1000 M nitric acid?

●How many grams of sodium hydroxide are needed to neutralize 20 mL of 0.150 M Sulfuric acid solution?

●How many liters of 0.500 M hydrochloric acid are needed to react completely with 0.100 mole of lead(II) nitrate?

Titrations

●Used to determine the _________________ of a particular solute in a solution.

●It involves combining a sample of the solution with a reagent solution of known concentration – called a _______________ solution.

●Titrations can be conducted using ____ reactions.

Equivalence Point

●The point at which stoichiometrically equivalent quantities are brought together is known as the ________________________ of the titration.

●In acid-base reactions, dyes known as _________________ are used to show the end point, they will change colors indicating that the equivalence point is near.

●End points are not always at the ______________ point, so care must be taken when selecting the indicator. (Chapter 17 will show us more.)

Practice Ppt. Titrations:

●The quantity of chloride ions in a municipal water supply is determined by titrating the sample with silver ion. The end point in this type of titration is marked by a change in color of a special type of indicator.

–Write the net ionic equation.

–How many grams of Cl^- are in a sample of water if 20.2 mL of 0.1 M Ag^+ is needed to react with all the chloride in the sample?

–If the sample has a mass of 10.0 g, what percent Cl^- does it contain?

Practice Redox Titrations

●A sample of an iron ore is dissolved in acid, and the iron is converted from Fe^{+3} to Fe^{2+}. The sample is then titrated with 47.20 mL of 0.02240 M MnO_4^- solution.

–Write the balanced redox reaction

–How many moles of MnO_4^- are added to the solution?

–How many moles of Fe^{2+} were in the sample?

–How many grams of iron were in the sample?

–If the sample had a mass of 0.8890 g, what is the percentage of iron in the sample?

Practice Acid-Base Titrations

●One commercial method used to peel potatoes is to soak them in a solution of NaOH for a short time, remove them from the NaOH, and spray off the peel. The concentration of NaOH is normally in the range of 3 to 6 M. The NaOH is analyzed periodically In one such analysis, 45.7 mL of 0.500 M H_2SO_4 is required to neutralize a 20 mL sample of NaOH solution. What is the concentration of the NaOH solution?

Distributed Practice Problem

●A sample of 70.5 mg of potassium phosphate is added to 15.0 mL of 0.050 M silver nitrate, resulting in the formation of a precipitate.

–Write the molecular equation for the reaction.

–What is the limiting reactant in the reaction?

–Calculate the theoretical yield, in grams, of the precipitate that forms.