Outline

- Precipitation Reactions
- Acid-Base Reactions
- Net-Ionic Equations
- Oxidation-Reduction Reactions
- Classification of Reactions
- Titrations

Precipitation Reactions

Aqueous solutions are those in which water is the dissolving medium

Solution – a homogeneous (uniform composition) mixture

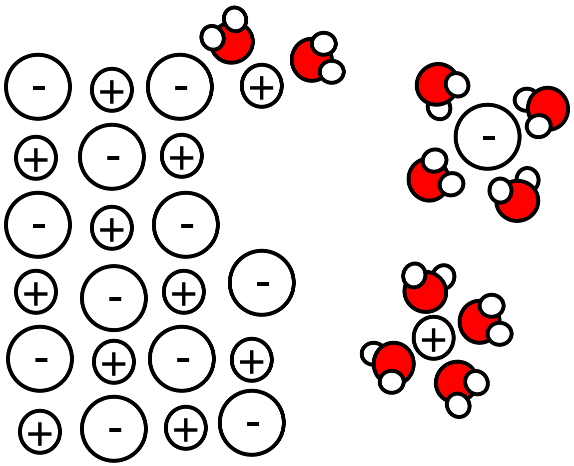
Solvent – the major component of a solution

Solute – the minor component of a solution

Ability of water to dissolve substances results from its unequal charge distribution

"Charged ends" of water molecule interact with solute molecules (ions)

Salts (ionic compounds) dissolve in a process called <u>dissociation</u>



"Negative end" attracted to cation

"Positive end" attracted to anion

Ions surrounded by water molecules are said to be <u>solvated</u>

Ions in solution can react to form insoluble substance (precipitate)

Reactions that form precipitates are <u>precipitation reactions</u>

Products of precipitation reactions determined from ion exchange and solubility rules

$$2NaCl(aq) + Pb(NO_3)_2(aq) \rightarrow 2NaNO_3(aq) + PbCl_2(s)$$

$$BaBr_2(aq) + Na_2SO_4(aq) \rightarrow BaSO_4(s) + 2NaBr(aq)$$

$$2KOH(aq) + CaCl_2(aq) \rightarrow 2KCl(aq) + Ca(OH)_2(s)$$

$$3Na_2S(aq) + 2FeI_3(aq) \rightarrow 6NaI(aq) + Fe_2S_3(s)$$

Acid-Base Reactions

Brønsted – Lowry acids are substances capable of donating hydrogen ions (H^+)

Brønsted – Lowry bases are substances capable of accepting hydrogen ions (H^+)

Acids react with bases by transferring hydrogen ions (H^+)

$$HCl(aq) + NaOH(aq) \rightarrow NaCl(aq) + H_2O(l)$$

Acid-base reactions are termed neutralization reactions…

the reactions produce "hot salty water"!

Predict the products…

$HBr(aq) + LiOH(aq) \rightarrow LiBr(aq) + H_2O(l)$

$H_2SO_4(aq) + Ba(OH)_2 \rightarrow BaSO_4(s) + 2H_2O(l)$

Some products in aqueous reactions are gaseous…

$H_2S(aq) \rightarrow H_2S(g)$

$H_2CO_3(aq) \rightarrow H_2O(l) + CO_2(g)$

$H_2SO_3(aq) \rightarrow H_2O(l) + SO_2(g)$

$NH_4OH(aq) \rightarrow H_2O(l) + NH_3(g)$

If water accepts a hydrogen ion it forms hydronium ion

$$H_2O(l) + H^+(aq) \rightarrow H_3O^+(aq)$$

Acid molecules undergo ionization when dissolved into water

$$HCl(aq) + H_2O(l) \rightarrow H_3O^+(aq) + Cl^-(aq)$$

Acids that ionize completely are strong acids

HCl, HBr, HI, H_2SO_4, HNO_3, $HClO_3$, $HClO_4$

Bases that dissociate completely are strong bases

alkali metal hydroxides, $Ca(OH)_2$, $Sr(OH)_2$, $Ba(OH)_2$

Net-Ionic Equations

formula equation: all reactants and products, no individual ions

total ionic equation: all reactants and products are given as ions

net ionic equation: includes only those species involved in reaction

In net-ionic equations…

- Soluble salts, strong acids, and strong bases are written in “ionic form”
- Insoluble salts, weak acids, weak bases, and soluble molecular compounds are written in “molecular form”

Write in net-ionic form…

$CaCl_2(aq) + Pb(NO_3)_2(aq) \rightarrow Ca(NO_3)_2(aq) + PbCl_2(s)$

nie: $2Cl^-(aq) + Pb^{2+}(aq) \rightarrow PbCl_2(s)$

$CdS(s) + 2HNO_3(aq) \rightarrow Cd(NO_3)_2(aq) + H_2S(g)$

nie: $CdS(s) + 2H^+(aq) \rightarrow Cd^{2+}(aq) + H_2S(g)$

$2HCl(aq) + Na_2CO_3(aq) \rightarrow 2NaCl(aq) + H_2O(l) + CO_2(g)$

nie: $2H^+(aq) + CO_3^{2-}(aq) \rightarrow H_2O(l) + CO_2(g)$

<u>Spectator ions</u> do not participate in the chemical reaction…

Oxidation-Reduction Reactions

Reactions involving the transfer of electrons are oxidation-reduction reactions (redox reactions)

- Oxidation is the loss of electrons
- Reduction is the gain of electrons

Oxidation always accompanies reduction!

Oxidation numbers are used to keep track of electrons in redox reactions

- Oxidation increases oxidation number
- Reduction decreases oxidation number

The oxidation number…

…of atoms in elemental state is 0

…of monatomic ions is equal to charge of ions

…is +1 for Group I metals and +2 for Group II metals

…is usually +1 for hydrogen (except with metal hydrides)

…is usually -2 for oxygen (except with peroxides)

…is negative for the most electronegative atom in a compounds (and equal to charge of the ion)

The sum of oxidation numbers…

…in a compound is equal to zero

…in polyatomic ions is equal to charge of ion

Reducing agents cause something to be reduced (it's oxidized)

Usually: metals, H_2, elemental C

Oxidizing agents cause something to be oxidized (it's reduced)

Usually: halogens, O_2, $Cr_2O_7^{2-}$, MnO_4^-, HNO_3, H_2O_2

Products of redox reactions…

$Cr_2O_7^{2-} \rightarrow Cr^{3+}$ (acidic)

$MnO_4^{-} \rightarrow Mn^{2+}$ (acidic)

$MnO_4^{-} \rightarrow MnO_2$ (basic)

$HNO_3 \rightarrow NO_2$

$H_2O_2 \rightarrow H_2O$

In redox reactions, electrons gained by one element must equal electrons lost by another element!

Redox reactions balanced with the half-reaction method

1. Determine oxidation numbers

2. Write half-reactions for oxidation and reduction

3. Balance half-reactions with "MOHe"
   - M – miscellaneous atoms
   - O – oxygen atoms (with H_2O)
   - H – hydrogen atoms (with H^+)
   - e – electrons

4. Equalize electrons transferred

5. Combine half-reactions

$K_2Cr_2O_7 + Sn(NO_3)_2 \rightarrow$??? (assume acidic conditions)

$K^+ + Cr_2O_7^{2-} + Sn^{2+} + NO_3^- \rightarrow$???

$Cr_2O_7^{2-} + Sn^{2+} \rightarrow Cr^{3+} + Sn^{4+}$ (unbalanced)

red: $6e^- + 14H^+ + Cr_2O_7^{2-} \rightarrow 2Cr^{3+} + 7H_2O$

ox: $3Sn^{2+} \rightarrow 3Sn^{4+} + 6e^-$

redox: $14H^+ + Cr_2O_7^{2-} + 3Sn^{2+} \rightarrow 2Cr^{3+} + 3Sn^{4+} + 7H_2O$

$KMnO_4 + NaI \rightarrow$??? (assume basic conditions)

$K^+ + MnO_4^- + Na^+ + I^- \rightarrow$???

$MnO_4^- + I^- \rightarrow MnO_2 + I_2$ (unbalanced)

red: $6e^- + 8H^+ + 2MnO_4^- \rightarrow 2MnO_2 + 4H_2O$

ox: $6I^- \rightarrow 3I_2 + 6e^-$

redox: $8H^+ + 2MnO_4^- + 6I^- \rightarrow 2MnO_2 + 3I_2 + 4H_2O$

<u>redox</u>: $4H_2O + 2MnO_4^- + 6I^- \rightarrow 2MnO_2 + 3I_2 + 8OH^-$

Classification of Reactions

combination:	simpler substances form complex substance
	$A + B \rightarrow AB$
decomposition:	complex substance forms simpler substances
	$AB \rightarrow A + B$
single-displacement:	one element displaces another
	$A + BX \rightarrow B + AX$
double-displacement:	two elements (groups) displace one another
	$AX + BY \rightarrow AY + BX$

Titrations

Titration is a procedure for determining amount of a substance in solution

Titrant of known concentration is added to analyte of unknown concentration

The complete reaction between titrant and analyte occurs at the equivalence point

<u>Molarity</u> (M) is the number of moles of solute per liter of solution

$$\text{Molarity} = \frac{\text{mol solute}}{\text{L solution}}$$

Dilution is when more solvent is added to lower the concentration of the solution

$$M_c \times V_c = M_d \times V_d$$

How many mL's of 0.45 M $K_2Cr_2O_7$ are needed to titrate 25.0 mL of 0.23 M $Sn(NO_3)_2$?

$$14H^+ + Cr_2O_7^{2-} + 3Sn^{2+} \rightarrow 2Cr^{3+} + 3Sn^{4+} + 7H_2O$$

$$25.0\ \text{mL} \times \frac{0.23\ \text{mol}\ Sn^{2+}}{\text{L}} \times \frac{1\ \text{mol}\ Cr_2O_7^{2-}}{3\ \text{mol}\ Sn^{2+}} \times \frac{1\ \text{L}}{0.45\ \text{mol}\ Cr_2O_7^{2-}} = \underline{4.3\ \text{mL}}$$

What is the concentration of a NaCl solution if a 10.0 mL sample require 42.3 mL of 0.25 M $KMnO_4$ to reach the equivalence point under acidic conditions?

$KMnO_4 + NaCl \rightarrow ???$

$MnO_4^- + Cl^- \rightarrow Mn^{2+} + Cl_2$

$16H^+ + 2MnO_4^- + 10Cl^- \rightarrow 2Mn^{2+} + 5Cl_2 + 8H_2O$

$$42.3\ \text{mL} \times \frac{0.25\ \text{mol}\ MnO_4^-}{\text{L}} \times \frac{10\ \text{mol}\ Cl^-}{2\ \text{mol}\ MnO_4^-} = 5\underline{2}.87\ \text{mmol}\ Cl^-$$

$$\frac{5\underline{2}.87\ \text{mmol}\ Cl^-}{10.0\ \text{mL}} = 5.3\ \text{M NaCl}$$

How many grams of copper can be oxidized to copper(II) by 55 mL of 1.0 M HNO_3, assuming complete reaction?

$Cu + HNO_3 \rightarrow ???$

$Cu + NO_3^- \rightarrow Cu^{2+} + NO_2$

$4H^+ + Cu + 2NO_3^- \rightarrow Cu^{2+} + 2NO_2 + 2H_2O$

$$55 \times 10^{-3} L \times \frac{1.0 \text{ mol } NO_3^-}{L} \times \frac{1 \text{ mol Cu}}{2 \text{ mol } NO_3^-} \times \frac{63.55 \text{ g}}{1 \text{ mol}} = \underline{1.7 \text{ g Cu}}$$