Chemistry, The Central Science, 10th edition
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Chapter 4
Aqueous Reactions and Solution Stoichiometry

Pentacarbonyliron reacts with phosphorous trifluoride and hydrogen, releasing carbon monoxide:

$$Fe(CO)_5 + PF_3 + H_2 \rightarrow Fe(CO)_2(PF_3)_2(H)_2 + CO \text{ (not balanced}$$

The reaction of 5.0 mol of $Fe(CO)_5$, 8.0 mol of PF_3 and 6.0 mol of H_2 will release __________ mol of CO.

A) 15

B) 5.0

C) 24

D) 6.0

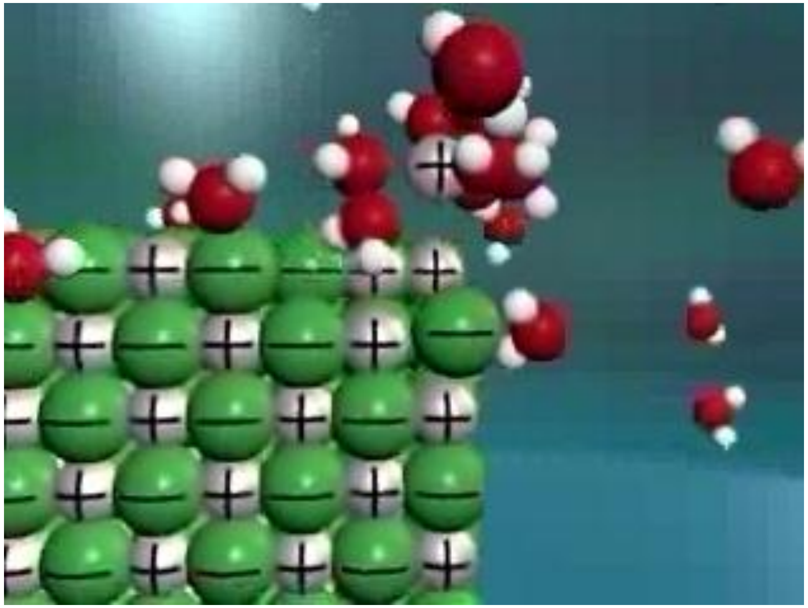
E) 12

Aqueous Reactions

Solutions:

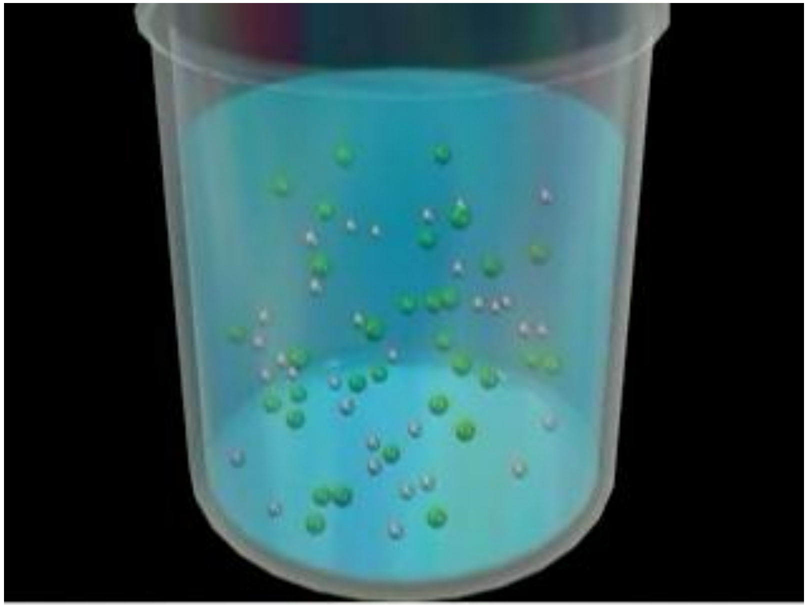
- Homogeneous mixtures of two or more pure substances.
- The solvent is present in greatest abundance.
- All other substances are solutes.

Dissociation



- When an ionic substance dissolves in water, the solvent pulls the individual ions from the crystal and solvates them.
- This process is called dissociation.

Electrolytes

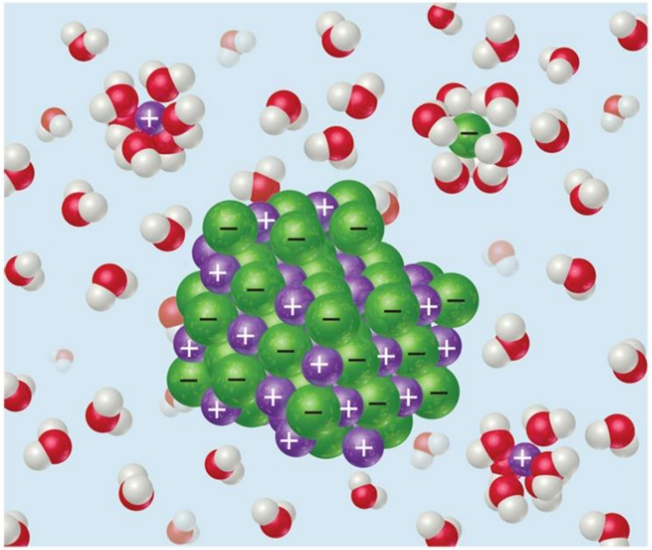


- Substances that dissociate into ions when dissolved in water.
- A nonelectrolyte may dissolve in water, but it does not dissociate into ions when it does so.

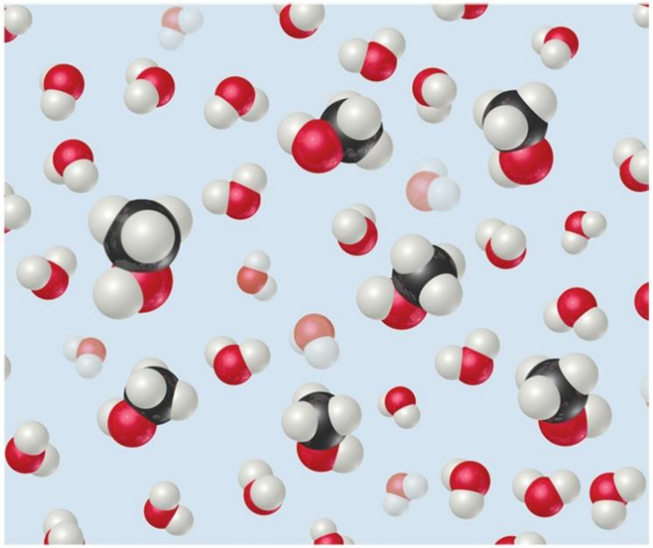
Electrolytes and Nonelectrolytes

	Strong Electrolyte	Weak Electrolyte	Nonelectrolyte
Ionic	All	None	None
Molecular	Strong acids (see Table 4.2)	Weak acids (H . . .) Weak bases (NH_3)	All other compounds

Soluble ionic compounds tend to be electrolytes.



Electrolytes and Nonelectrolytes



Molecular compounds tend to be nonelectrolytes, except for acids and bases.

Electrolytes

- A strong electrolyte dissociates completely when dissolved in water.
- A weak electrolyte only dissociates partially when dissolved in water.

	Strong Electrolyte	Weak Electrolyte	Nonelectrolyte
Ionic	All	None	None
Molecular	Strong acids (see Table 4.2)	Weak acids (H . . .)	
		Weak bases (NH_3)	All other compounds

Strong Acids	Strong Bases
Hydrochloric, HCl	Group 1A metal hydroxides ($LiOH$, $NaOH$, KOH, $RbOH$, $CsOH$)
Hydrobromic, HBr	Heavy group 2A metal hydroxides [$Ca(OH)_2$, $Sr(OH)_2$, $Ba(OH)_2$]
Hydroiodic, HI	
Chloric, $HClO_3$	
Perchloric, $HClO_4$	
Nitric, HNO_3	
Sulfuric, H_2SO_4	

Strong Electrolytes Are…

Strong Acids	Strong Bases
Hydrochloric, HCl	Group 1A metal hydroxides (LiOH, NaOH, KOH, RbOH, CsOH)
Hydrobromic, HBr	Heavy group 2A metal hydroxides [$Ca(OH)_2$, $Sr(OH)_2$, $Ba(OH)_2$]
Hydroiodic, HI	
Chloric, $HClO_3$	
Perchloric, $HClO_4$	
Nitric, HNO_3	
Sulfuric, H_2SO_4	

Solubility of Ionic Compounds

Soluble Ionic Compounds		Important Exceptions
Compounds containing	NO_3^-	None
	$C_2H_3O_2^-$	None
	Cl^-	Compounds of Ag^+, Hg_2^{2+}, and Pb^{2+}
	Br^-	Compounds of Ag^+, Hg_2^{2+}, and Pb^{2+}
	I^-	Compounds of Ag^+, Hg_2^{2+}, and Pb^{2+}
	SO_4^{2-}	Compounds of Sr^{2+}, Ba^{2+}, Hg_2^{2+}, and Pb^{2+}

Insoluble Ionic Compounds		Important Exceptions
Compounds containing	S^{2-}	Compounds of NH_4^+, the alkali metal cations, and Ca^{2+}, Sr^{2+}, and Ba^{2+}
	CO_3^{2-}	Compounds of NH_4^+ and the alkali metal cations
	PO_4^{3-}	Compounds of NH_4^+ and the alkali metal cations
	OH^-	Compounds of the alkali metal cations, and NH_4^+, Ca^{2+}, Sr^{2+}, and Ba^{2+}

A strong electrolyte is one that ___________ completely in solution.

A) reacts
B) dissociates
C) disappears
D) ionizes

Precipitation Reactions

When one mixes ions that form compounds that are insoluble (as could be predicted by the solubility guidelines), a precipitate is formed.

Metathesis (Exchange) Reactions

- Metathesis comes from a Greek word that means “to transpose”

$$AgNO_{3\,(aq)} + KCl_{(aq)} \longrightarrow$$

Metathesis (Exchange) Reactions

- Metathesis comes from a Greek word that means "to transpose"
- It appears as if the ions in the reactant compounds exchange, or transpose, ions
- Pay attention to the fact that the polyatomic ions are transposing as one unit.

$$AgNO_{3\,(aq)} + KCl_{\,(aq)} \longrightarrow AgCl_{\,(s)} + KNO_{3\,(aq)}$$

Solution Chemistry

- It is helpful to pay attention to *exactly* what species are present in a reaction mixture (i.e., solid, liquid, gas, aqueous solution).
- If we are to understand reactivity, we must be aware of just what is changing during the course of a reaction.

Which one of the following is **<u>not</u>** a strong acid.

A. Sulfuric acid

B. Nitric acid

C. Acetic acid

D. Hydroiodic acid

Molecular Equation

The molecular equation lists the reactants and products in their molecular form.

$$AgNO_3\,(aq) + KCl\,(aq) \longrightarrow AgCl\,(s) + KNO_3\,(aq)$$

Ionic Equation

- In the ionic equation all strong electrolytes (strong acids, strong bases, and soluble ionic salts) are dissociated into their ions.
- This more accurately reflects the species that are found in the reaction mixture.

$$Ag^{+}\,(aq) + NO_3^{-}\,(aq) + K^{+}\,(aq) + Cl^{-}\,(aq) \longrightarrow$$
$$AgCl\,(s) + K^{+}\,(aq) + NO_3^{-}\,(aq)$$

Net Ionic Equation

- To form the net ionic equation, cross out anything that does not change from the left side of the equation to the right.

$$Ag^{+}(aq) + \cancel{NO_3^{-}}(aq) + \cancel{K^{+}}(aq) + Cl^{-}(aq) \longrightarrow$$

$$AgCl\,(s) + \cancel{K^{+}}(aq) + \cancel{NO_3^{-}}(aq)$$

Aqueous Reactions

Net Ionic Equation

- To form the net ionic equation, cross out anything that does not change from the left side of the equation to the right.
- The only things left in the equation are those things that change (i.e., react) during the course of the reaction.

$$Ag^{+}(aq) + Cl^{-}(aq) \longrightarrow AgCl(s)$$

Net Ionic Equation

- To form the net ionic equation, cross out anything that does not change from the left side of the equation to the right.
- The only things left in the equation are those things that change (i.e., react) during the course of the reaction.
- Those things that didn't change (and were deleted from the net ionic equation) are called spectator ions.

$$Ag^{+}(aq) + \cancel{NO_3^{-}(aq)} + \cancel{K^{+}(aq)} + Cl^{-}(aq) \longrightarrow$$
$$AgCl(s) + \cancel{K^{+}(aq)} + \cancel{NO_3^{-}(aq)}$$

Writing Net Ionic Equations

1. Write a balanced molecular equation.

2. Dissociate all strong electrolytes. Do not dissociate
   a. The solids,
   b. liquids and
   c. gases
   The liquids and gases are covalently linked so they will not dissociate in water
   d. the weak acids are also left as is, as they dissociate a negligible amount in water.

3. Cross out anything that remains unchanged from the left side to the right side of the equation.

4. Write the net ionic equation with the species that remain.

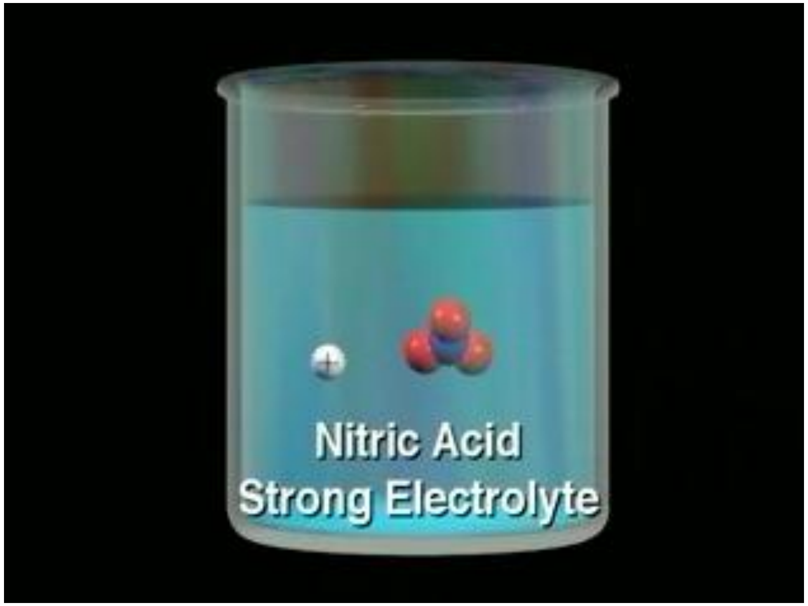
Writing Net Ionic Equations

$$(NH_4)_2SO_4(aq) + Ba(NO_3)_2(aq) \longrightarrow 2NH_4NO_3(aq) + BaSO_4(s)$$

Acids:

- Substances that increase the concentration of H^+ when dissolved in water (Arrhenius).
- Proton donors (Brønsted–Lowry).

Acids



There are only seven strong acids:

- Hydrochloric (HCl)
- Hydrobromic (HBr)
- Hydroiodic (HI)
- Nitric (HNO_3)
- Sulfuric (H_2SO_4)
- Chloric ($HClO_3$)
- Perchloric ($HClO_4$)

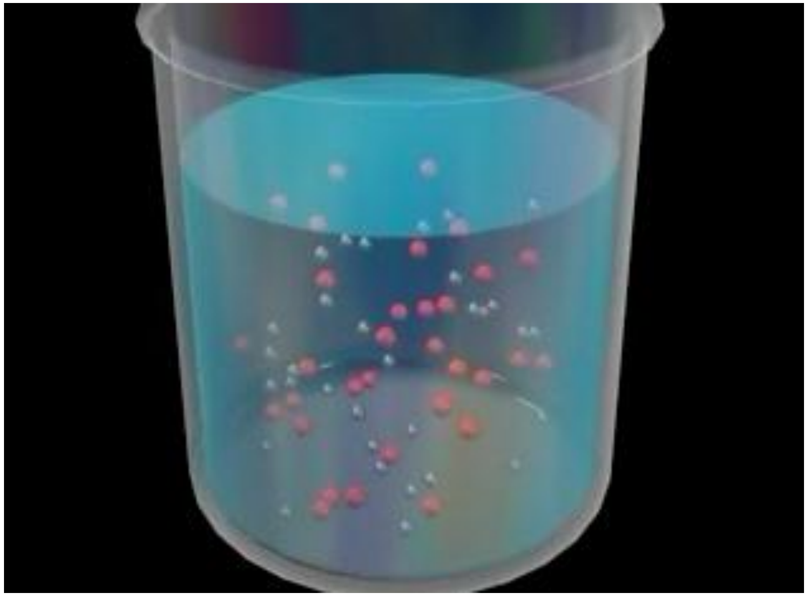
Bases:

- Substances that increase the concentration of OH^- when dissolved in water (Arrhenius).
- Proton acceptors (Brønsted–Lowry).

Bases

The strong bases are the soluble salts of hydroxide ion:

- Alkali metals
- Calcium
- Strontium
- Barium

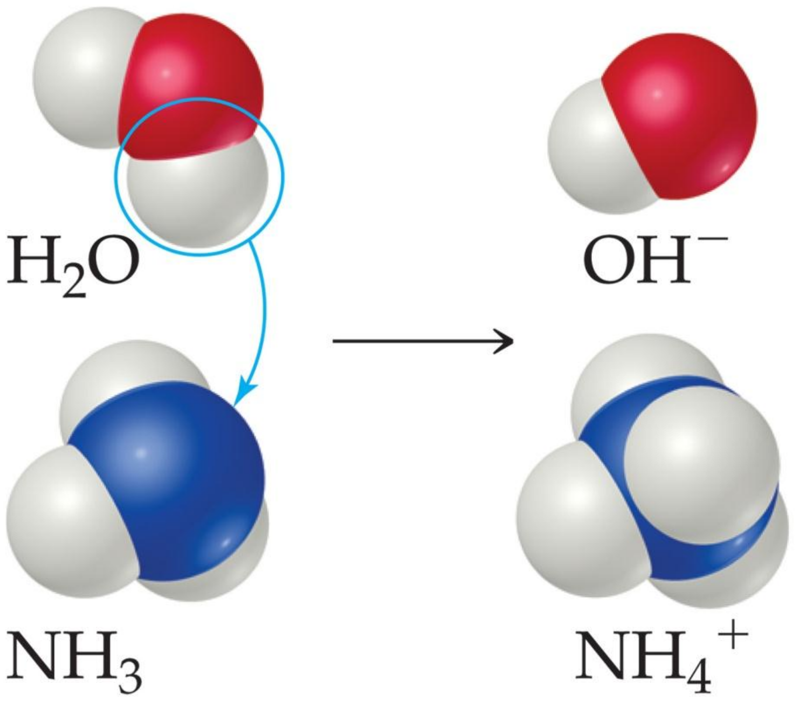


- Table 4.3

- Consider solutions in which 0.1 mol of each of the following compounds is dissolved in 1 L of water: $Ca(NO_3)_2$ (calcium nitrate), $C_6H_{12}O_6$ (glucose), CH_3COONa (sodium acetate), and CH_3COOH (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.

- ***Answers:*** $C_6H_{12}O_6$ (nonelectrolyte) $<$ CH_3COOH (weak electrolyte, existing mainly in the form of molecules with few ions) $<$ CH_3COONa (strong electrolyte that provides two ions, Na^+ and $CH_3COO^–$) $<$ $Ca(NO_3)_2$ (strong electrolyte that provides three ions, Ca^{2+} and 2 NO_3)

Acid-Base Reactions



In an acid-base reaction, the acid donates a proton (H^+) to the base.

Neutralization Reactions

Generally, when solutions of an acid and a base are combined, the products are a salt and water.

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

Neutralization Reactions

When a strong acid reacts with a strong base, the net ionic equation is…

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

$$H^+\ (aq) + Cl^-\ (aq) + Na^+\ (aq) + OH^-(aq) \longrightarrow Na^+\ (aq) + Cl^-\ (aq) + H_2O\ (l)$$

Neutralization Reactions

When a strong acid reacts with a strong base, the net ionic equation is…

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

$$H^+\ (aq) + Cl^-\ (aq) + Na^+\ (aq) + OH^-(aq) \longrightarrow Na^+\ (aq) + Cl^-\ (aq) + H_2O\ (l)$$

$$H^+\ (aq) + \cancel{Cl^-}\ (aq) + \cancel{Na^+}\ (aq) + OH^-\ (aq) \longrightarrow \cancel{Na^+}\ (aq) + \cancel{Cl^-}\ (aq) + H_2O\ (l)$$

Neutralization Reactions

Observe the reaction between Milk of Magnesia, $Mg(OH)_2$, and HCl.

$Mg(OH)_2$ is insoluble in water. When it reacts with stomach HCl it turns into soluble $MgCl_2$ and water

- Because the ions exchange partners, acid base reactions are metathesis reactions.

6) What are the spectator ions in the reaction between KOH (aq) and HNO_3(aq)?

A) K^+ and H^+

B) H^+ and OH^+

C) K^+ and NO_3^-

D) H^+ and NO_3^-

E) OH^- only

Combining aqueous solutions of BaI_2 and Na_2SO_4 affords a precipitate of $BaSO_4$. Which ion(s) is/are spectator ions in the reaction?

A) Na^+ only

B) Ba^{2+} only

C) Na^+ and I^- and

D) Ba^{2+} and SO_4^{2+}

E) SO_4^{2+} and I^-

Those of you who gave me the test for corrections, if it dose not say ***done*** in my handwriting, I need them back. I forgot to note the corrections in my grade book.

You can give it to me any day in the class or leave it in my mail box in the office.

- If you have a weak acid in a reaction and you need to write the net ionic equation, you do not dissociate it, as weak acids are only partially dissociated.

$$CH_3COOH(aq) + Ba(OH)_2(aq) \longrightarrow H_2O(l) + Ba(CH_3COO^-)_2(aq)$$

$$CH_3COOH(aq) + OH^-(aq) \longrightarrow H_2O(l) + CH_3COO^-(aq)$$

Gas-Forming Reactions

- These metathesis reactions do not give the product expected.
- The expected product decomposes to give a gaseous product (CO_2 or SO_2) along with water.

$$CaCO_3\,(s) + 2HCl\,(aq) \longrightarrow CaCl_2\,(aq) + (H_2CO_3)$$

$$CaCl_2\,(aq) + CO_2(g) + H_2O(l)$$

$$NaHCO_3\,(aq) + HBr\,(aq) \longrightarrow NaBr\,(aq) + (H_2CO_3)$$

$$NaBr\,(aq) + CO_2\,(g) + H_2O(l)$$

$$SrSO_3\,(s) + 2\,HI\,(aq) \longrightarrow SrI_2\,(aq) + (H_2SO_3)$$

$$SrI_2\,(aq) + SO_2\,(g) + H_2O(l)$$

Aqueous Reactions

Gas-Forming Reactions

Just as in the previous examples, a gas is formed as a product of this reaction:

$$Na_2S\ (aq) + H_2SO_4\ (aq) \longrightarrow Na_2SO_4\ (aq) + H_2S\ (g)$$

This reaction gives the predicted product, but you better carry it out in the hood, or you will be very unpopular!

1) The total concentration of ions in a 0.250 M solution of HCl is ___________.

A) essentially zero.

B) 0.125 M

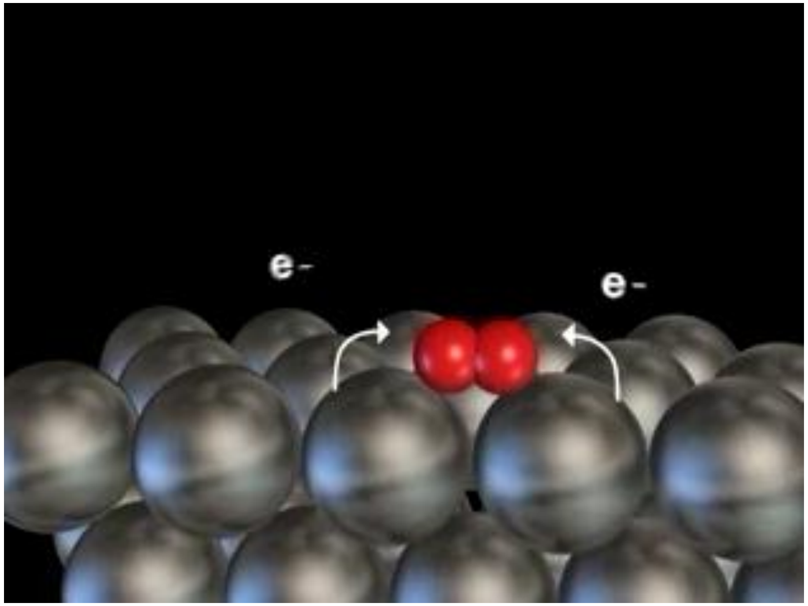
C) 0.250 M

D) 0.500 M

E) 0.750 M

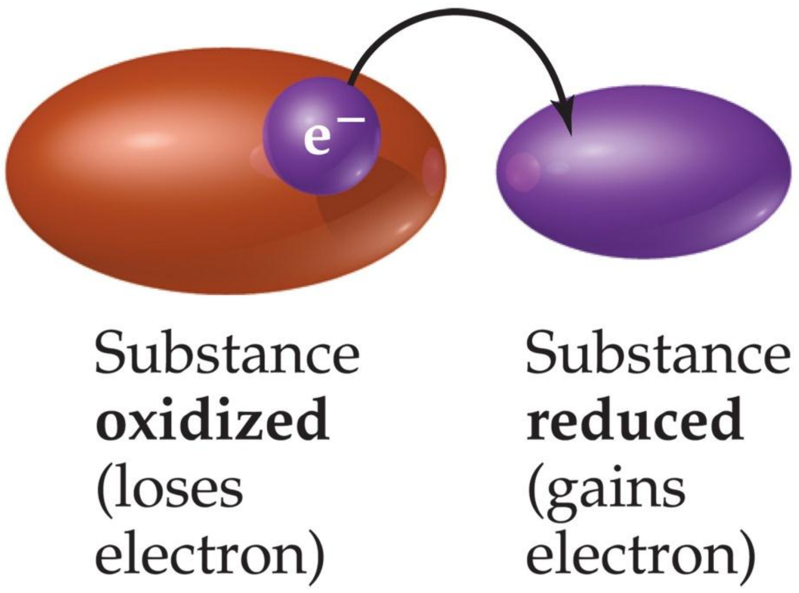
Oxidation-Reduction Reactions

- An oxidation occurs when an atom or ion *loses* electrons.
- A reduction occurs when an atom or ion *gains* electrons.



- Leo the lion goes ger
- Oil rig

Oxidation-Reduction Reactions



One cannot occur without the other.

Oxidation Numbers

To determine if an oxidation-reduction reaction has occurred, we assign an **oxidation number** to each element in a neutral compound or charged entity.

Oxidation Numbers

- Elements in their elemental form have an oxidation number of 0.
- The oxidation number of a monatomic ion is the same as its charge.

Oxidation Numbers

- Nonmetals tend to have negative oxidation numbers, although some are positive in certain compounds or ions.
  - Oxygen has an oxidation number of −2, except in the peroxide ion in which it has an oxidation number of −1.
  - Hydrogen is −1 when bonded to a metal, +1 when bonded to a nonmetal.

Oxidation Numbers

- Nonmetals tend to have negative oxidation numbers, although some are positive in certain compounds or ions.
  - Fluorine always has an oxidation number of −1.
  - The other halogens have an oxidation number of −1 when they are negative; they can have positive oxidation numbers, however, most notably in oxyanions.

Oxidation Numbers

- The sum of the oxidation numbers in a neutral compound is 0.
- The sum of the oxidation numbers in a polyatomic ion is the charge on the ion.

Which of the following statements is(are) false?

Oxidation and reduction

A. cannot occur independently of each other.

B. accompany all chemical changes.

C. describe the loss and gain of electron(s), respectively.

D. result in a change in the oxidation states of the species involved.

Determine the oxidation number of sulfur in each of the following: (a) H_2S, (b) S_8, (c) SCl_2, (d) Na_2SO_3, (e) SO_4^{2-}.

(a) H_2S: Hydrogen is −1 when bonded to a metal, +1 when bonded to a nonmetal.

$2(+1) + x = 0, \qquad x = -2$

(b) S_8: Because this is an elemental form of sulfur, the oxidation number of S is 0

(c) SCl_2: The halogens other than F have an oxidation number of −1 when they are in binary compounds.

$x + 2(–1) = 0 , \qquad x = +2$

(d) Na_2SO_3 :Sodium, an alkali metal, always has an oxidation number of +1 in its compounds

Oxygen has a common oxidation state of –2

$2(+1) + x + 3(-2) = 0 \quad x =+ 4$

(e) SO_4^{2-} : The oxidation state of O is –2 . This is not a neutral entity so the sum of the oxidation numbers is equal to the charge.

$x + 4(–2) = –2, \quad x = +6$

Is the following a redox reaction

$2Ca\ (s) + O_2(g) \rightarrow 2\ CaO\ (s)$

You have to see what happens to the oxidation number of the different elements

If the oxidation number changes the reaction is a redox reaction

All combustion reactions are redox reaction as the elemental oxygen (oxidation number of 0) changes to compounds oxygen (oxidation number -2)

Q 4.51

$$PbS\ (s) + 4\ H_2O_2 \rightarrow PbSO_4\ (s) + 4\ H_2O$$

Which element is oxidized

A. Pb

B . S

C. H

D. O

Oxidation of Metals by Acids and Salts

The oxidation of a metal by an acid or a salt can follow the general pattern:

$A + BX \rightarrow AX + B$

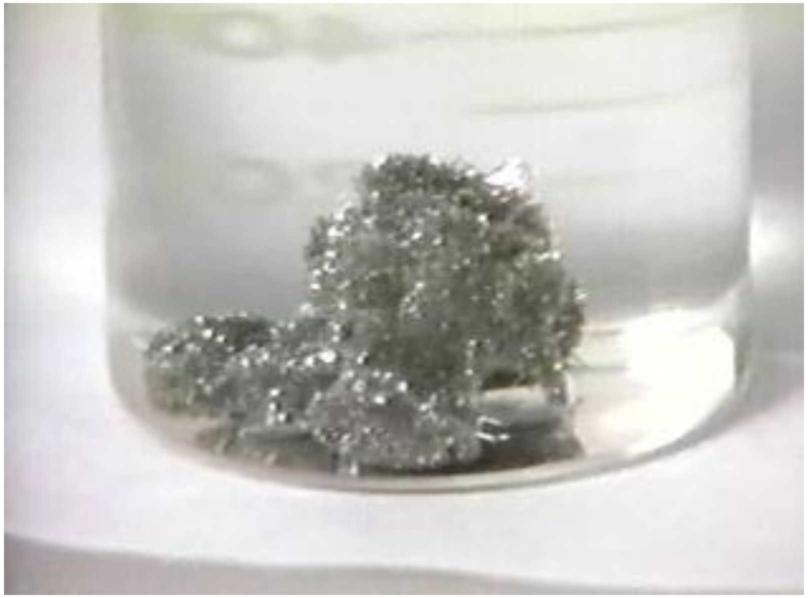
Specific examples

$Zn(s) + 2HBr(aq) \rightarrow ZnBr_2(aq) + H_2(g)$

$Mn(s) + Pb(NO_3)_2(aq) \rightarrow Mn(NO_3)_2(aq) + Pb(s)$

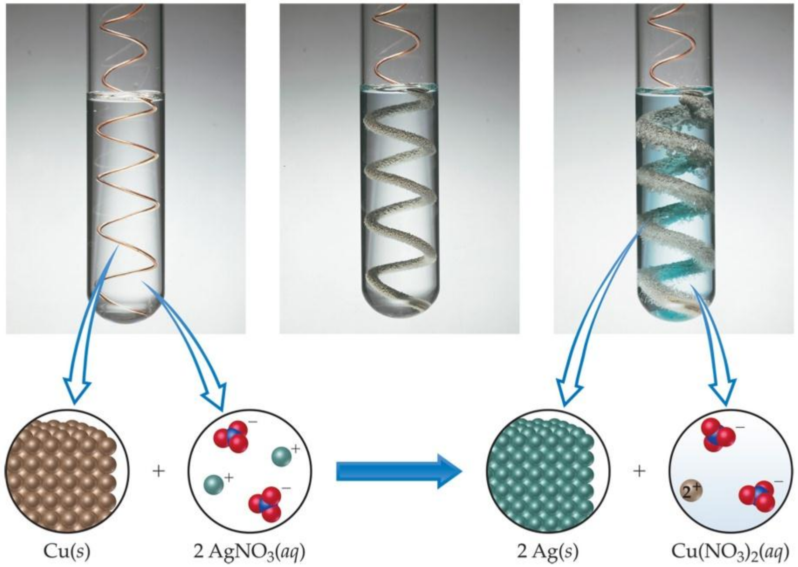
These reactions are called Displacement reactions.

Displacement Reactions



- In displacement reactions, ions oxidize an element.
- The ions, then, are reduced.

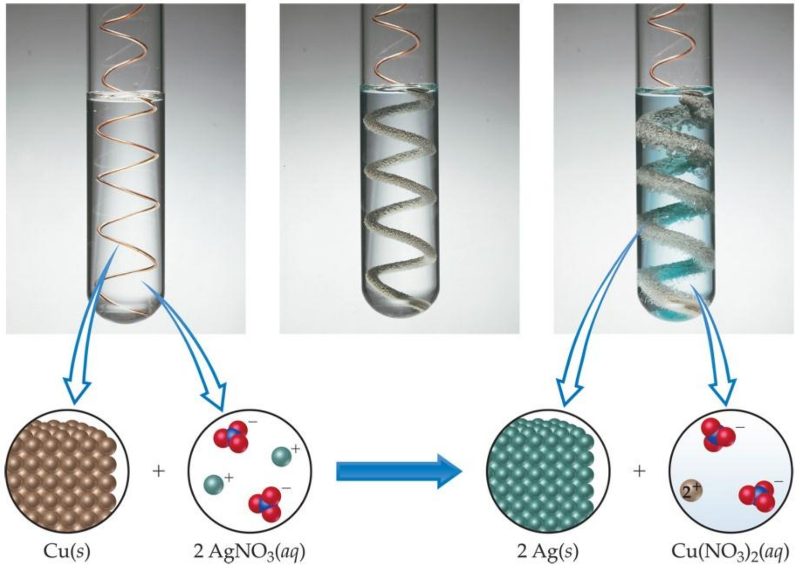
Displacement Reactions



In this reaction, silver ions oxidize copper metal.

$$Cu\ (s) + 2\ Ag^{+}\ (aq) \longrightarrow Cu^{2+}\ (aq) + 2\ Ag\ (s)$$

Displacement Reactions



The reverse reaction, however, does not occur.

$$Cu^{2+}(aq) + 2\,Ag(s) \not\longrightarrow Cu(s) + 2\,Ag^{+}(aq)$$

- Oxidizing and reducing agents.

- $Cu\ (s) + 2\ Ag^{+}\ (aq) \longrightarrow Cu^{2+}\ (aq) + 2\ Ag\ (s)$

Activity Series

Active Metals

Metal	Oxidation Reaction
Lithium	$Li(s) \longrightarrow Li^{+}(aq) + e^{-}$
Potassium	$K(s) \longrightarrow K^{+}(aq) + e^{-}$
Barium	$Ba(s) \longrightarrow Ba^{2+}(aq) + 2e^{-}$
Calcium	$Ca(s) \longrightarrow Ca^{2+}(aq) + 2e^{-}$
Sodium	$Na(s) \longrightarrow Na^{+}(aq) + e^{-}$
Magnesium	$Mg(s) \longrightarrow Mg^{2+}(aq) + 2e^{-}$
Aluminum	$Al(s) \longrightarrow Al^{3+}(aq) + 3e^{-}$
Manganese	$Mn(s) \longrightarrow Mn^{2+}(aq) + 2e^{-}$
Zinc	$Zn(s) \longrightarrow Zn^{2+}(aq) + 2e^{-}$
Chromium	$Cr(s) \longrightarrow Cr^{3+}(aq) + 3e^{-}$
Iron	$Fe(s) \longrightarrow Fe^{2+}(aq) + 2e^{-}$
Cobalt	$Co(s) \longrightarrow Co^{2+}(aq) + 2e^{-}$
Nickel	$Ni(s) \longrightarrow Ni^{2+}(aq) + 2e^{-}$
Tin	$Sn(s) \longrightarrow Sn^{2+}(aq) + 2e^{-}$
Lead	$Pb(s) \longrightarrow Pb^{2+}(aq) + 2e^{-}$
Hydrogen	$H_2(g) \longrightarrow 2\,H^{+}(aq) + 2e^{-}$
Copper	$Cu(s) \longrightarrow Cu^{2+}(aq) + 2e^{-}$
Silver	$Ag(s) \longrightarrow Ag^{+}(aq) + e^{-}$
Mercury	$Hg(l) \longrightarrow Hg^{2+}(aq) + 2e^{-}$
Platinum	$Pt(s) \longrightarrow Pt^{2+}(aq) + 2e^{-}$
Gold	$Au(s) \longrightarrow Au^{3+}(aq) + 3e^{-}$

Noble Metals

Any Metal in the series can be oxidized by the ion of the elements below it

$$Cu\,(s) + 2\,Ag^{+}\,(aq) \longrightarrow Cu^{2+}\,(aq) + 2\,Ag\,(s)$$

Activity Series

Active Metals

Metal	Oxidation Reaction
Lithium	$Li(s) \longrightarrow Li^{+}(aq) + e^{-}$
Potassium	$K(s) \longrightarrow K^{+}(aq) + e^{-}$
Barium	$Ba(s) \longrightarrow Ba^{2+}(aq) + 2e^{-}$
Calcium	$Ca(s) \longrightarrow Ca^{2+}(aq) + 2e^{-}$
Sodium	$Na(s) \longrightarrow Na^{+}(aq) + e^{-}$
Magnesium	$Mg(s) \longrightarrow Mg^{2+}(aq) + 2e^{-}$
Aluminum	$Al(s) \longrightarrow Al^{3+}(aq) + 3e^{-}$
Manganese	$Mn(s) \longrightarrow Mn^{2+}(aq) + 2e^{-}$
Zinc	$Zn(s) \longrightarrow Zn^{2+}(aq) + 2e^{-}$
Chromium	$Cr(s) \longrightarrow Cr^{3+}(aq) + 3e^{-}$
Iron	$Fe(s) \longrightarrow Fe^{2+}(aq) + 2e^{-}$
Cobalt	$Co(s) \longrightarrow Co^{2+}(aq) + 2e^{-}$
Nickel	$Ni(s) \longrightarrow Ni^{2+}(aq) + 2e^{-}$
Tin	$Sn(s) \longrightarrow Sn^{2+}(aq) + 2e^{-}$
Lead	$Pb(s) \longrightarrow Pb^{2+}(aq) + 2e^{-}$
Hydrogen	$H_2(g) \longrightarrow 2H^{+}(aq) + 2e^{-}$
Copper	$Cu(s) \longrightarrow Cu^{2+}(aq) + 2e^{-}$
Silver	$Ag(s) \longrightarrow Ag^{+}(aq) + e^{-}$
Mercury	$Hg(l) \longrightarrow Hg^{2+}(aq) + 2e^{-}$
Platinum	$Pt(s) \longrightarrow Pt^{2+}(aq) + 2e^{-}$
Gold	$Au(s) \longrightarrow Au^{3+}(aq) + 3e^{-}$

Noble Metals

Only the metals above hydrogen in the activity series are able to react with acids to release hydrogen gas

Copper will not react with an acid to give H_2 gas but Ni will

Aqueous Reactions

$$PbS\ (s) + 4\ H_2O_2 \rightarrow PbSO_4\ (s) + 4\ H_2O$$

What is reduced.

A. Pb

B . S

C. H

D. O

Aqueous Reactions

Molarity

- Two solutions can contain the same compounds but be quite different because the proportions of those compounds are different.
- Molarity is one way to measure the concentration of a solution.

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

Making a Solution

(a) (b) (c) (d)

Calculate the molarity of a solution made by dissolving 23.4 g of sodium sulfate (Na_2SO_4) in enough water to form 125 mL of solution.

$$\text{Moles } Na_2SO_4 = (23.4\ \text{g}\ Na_2SO_4)\left(\frac{1\ \text{mol}\ Na_2SO_4}{142\ \text{g}\ Na_2SO_4}\right) = 0.165\ \text{mol}\ Na_2SO_4$$

$$\text{Liters soln} = (125\ \text{mL})\left(\frac{1\ \text{L}}{1000\ \text{mL}}\right) = 0.125\ \text{L}$$

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

$$\text{Molarity} = \frac{0.165\ \text{mol}\ Na_2SO_4}{0.125\ \text{L soln}} = 1.32\ \frac{\text{mol}\ Na_2SO_4}{\text{L soln}} = 1.32\ M$$

What are the molar concentrations of the ions present in a 0.025 *M* aqueous solution of calcium nitrate?

a. 0.025 M
b. 0.050 M
c. 0.075 M
d. 0.100 M

- How would you make 200.0 ml of 0.5 M NaCl solution.
- First calculate how many moles of NaCl are needed.
- Then convert the moles to g of NaCl

$$M = \frac{\text{mol}}{\text{L}} \qquad \text{mol} = ML = 0.5\,\frac{\text{mol}}{\text{L}} \times 0.2\text{L} = 0.1 \text{ mol NaCl}$$

$$0.1 \text{ mol NaCl} \times \frac{58.442 \text{ g NaCl}}{1 \text{ mol NaCl}} = 5.844 \text{ g NaCl}$$

Aqueous Reactions

- How many grams of Na_2SO_4 are there in 15 mL of 0.50 *M* Na_2SO_4? **(b)** How many milliliters of 0.50 *M* Na_2SO_4 solution are needed to provide 0.038 mol of this salt?

Dilution

Lemonade Concentrate

Dilution

$$M_iV_i = M_fV_f$$

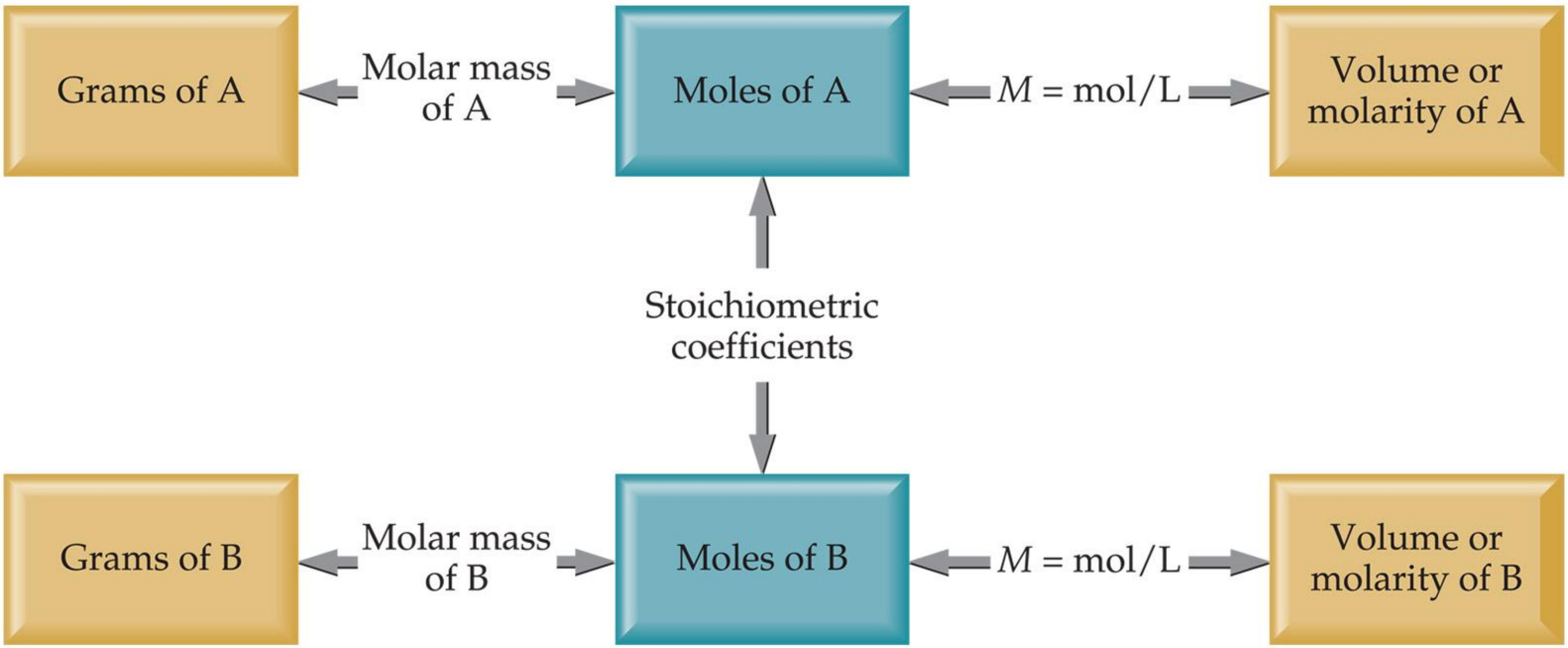
How many milliliters of 3.0 *M* H_2SO_4 are needed to make 450 mL of 0.10 *M* H_2SO_4?

- **(b)** How many milliliters of 5.0 *M* $K_2Cr_2O_7$ solution must be diluted to prepare 250 mL of 0.10 *M* solution?

- **(c)** If 10.0 mL of a 10.0 *M* stock solution of NaOH is diluted to 250 mL, what is the concentration of the resulting solution?

- Stoichiometric Calculations require the chemicals to be in molar quantities
- When a gram amount is given it can directly be changes to moles.
- In solutions the molarity and the volume are given and can be used to calculate the number f moles
- The rest is the same as in any other problem……

Using Molarities in Stoichiometric Calculations



- How many grams of $Ca(OH)_2$ are needed to neutralize 25.0 mL of 0.100 *M* HNO_3?

$$2\,HNO_3(aq) + Ca(OH)_2(s) \longrightarrow 2\,H_2O(l) + Ca(NO_3)_2(aq)$$

M=moles/L   moles = M x L

$$\text{moles } HNO_3 = L_{HNO_3} \times M_{HNO_3} = (0.0250\ \cancel{L})\left(0.100\ \frac{\text{mol } HNO_3}{\cancel{L}}\right)$$
$$= 2.50 \times 10^{-3}\ \text{mol } HNO_3$$

$$\text{grams } Ca(OH)_2 = (2.50 \times 10^{-3}\ \cancel{\text{mol } HNO_3})\left(\frac{1\ \cancel{\text{mol } Ca(OH)_2}}{2\ \cancel{\text{mol } HNO_3}}\right)\left(\frac{74.1\ \text{g } Ca(OH)_2}{1\ \cancel{\text{mol } Ca(OH)_2}}\right)$$
$$= 0.0926\ \text{g } Ca(OH)_2$$

- **(a)** How many grams of NaOH are needed to neutralize 20.0 mL of 0.150 *M* H_2SO_4 solution?

(b) How many liters of 0.500 *M* HCl(*aq*) are needed to react completely with 0.100 mol of $Pb(NO_3)_2$(*aq*), forming a precipitate of $PbCl_2$(*s*)?

- $Pb(NO_3)_2(aq), + 2HCl \rightarrow PbCl_2(s) + 2HNO_3\,(aq)$

Calculate the oxidation number of Cr in $Cr_2O_7^-$

A. +2

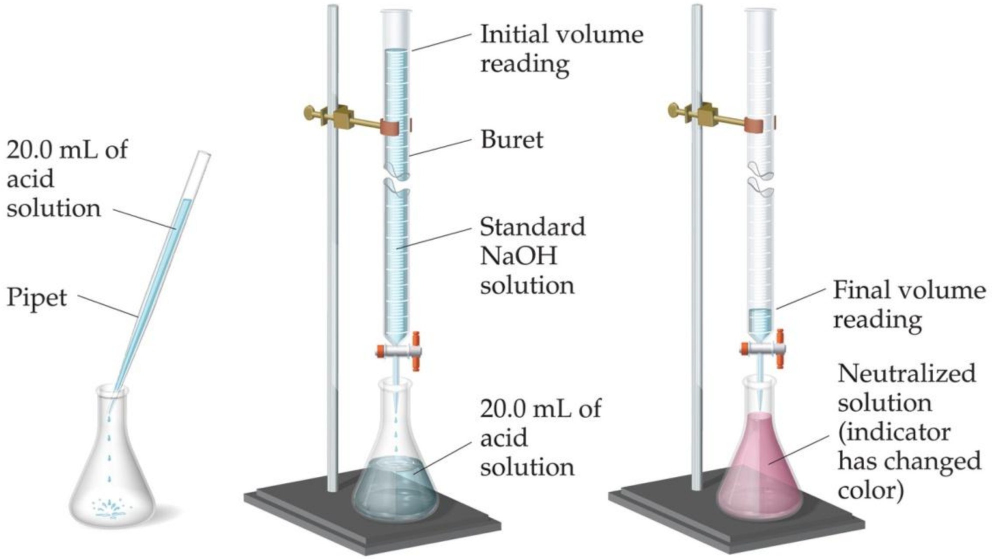
B. + 4

C. +6

D. +8

Aqueous Reactions

Titration



The analytical technique in which one can calculate the concentration of a solute in a solution.

Titration

The quantity of Cl^- in a municipal water supply is determined by titrating the sample with Ag^+. The reaction taking place during the titration is

$$Ag^+(aq) + Cl^-(aq) \longrightarrow AgCl(s)$$

The end point in this type of titration is marked by a change in color of a special type of indicator. **(a)** How many grams of chloride ion are in a sample of the water if 20.2 mL of 0.100 *M* Ag^+ is needed to react with all the chloride in the sample?

$$\text{moles } Ag^+ = (20.2 \cancel{\text{mL soln}})\left(\frac{1\ \cancel{\text{L soln}}}{1000\ \cancel{\text{mL soln}}}\right)\left(0.100\ \frac{\text{mol } Ag^+}{\cancel{\text{L soln}}}\right)$$
$$= 2.02 \times 10^{-3} \text{ mol } Ag^+$$

$$\text{grams } Cl^- = (2.02 \times 10^{-3}\ \cancel{\text{mol } Ag^+})\left(\frac{1\ \cancel{\text{mol } Cl^-}}{1\ \cancel{\text{mol } Ag^+}}\right)\left(\frac{35.5 \text{ g } Cl^-}{1\ \cancel{\text{mol } Cl^-}}\right)$$
$$= 7.17 \times 10^{-2} \text{ g } Cl^-$$

A sample of an iron ore is dissolved in acid, and the iron is converted to Fe^{2+}. The sample is then titrated with 47.20 mL of 0.02240 *M* MnO_4^- solution. The oxidation-reduction reaction that occurs during titration is as follows:

$$MnO_4^-(aq) + 5\,Fe^{2+}(aq) + 8\,H^+(aq) \longrightarrow Mn^{2+}(aq) + 5\,Fe^{3+}(aq) + 4\,H_2O(l)$$

(a) How many moles of MnO_4^- were added to the solution?
(b) How many moles of Fe^{2+} were in the sample?
(c) How many grams of iron were in the sample?
(d) If the sample had a mass of 0.8890 g, what is the percentage of iron in the sample

Answers: **(a)** 1.057×10^{-3} mol MnO_4^- **(b)** 5.286×10^{-3} mol Fe^{2+}, **(c)** 0.2952 g, **(d)** 33.21%

What is the molarity of an NaOH solution if 48.0 mL is needed to neutralize 35.0 mL of 0.144 *M* H_2SO_4?

$$H_2SO_4(aq) + 2\,NaOH(aq) \longrightarrow 2\,H_2O(l) + Na_2SO_4(aq)$$