Reactions in Aqueous Solution

Chapter 4

- Many chemical reactions and virtually all biological precesses take place in water – the so called universal solvent.
- ***Three*** categories of ractions occur in aqueous solutions:
  - precipitations reactions
  - acid-base reactions
  - redox reactions
- We begin with ***general properties of aqueous solutions***.

Solution, Solute & Solvent

A ***solution*** is a homogenous mixture of 2 or more substances.

The ***solute*** is the substance present in the **smaller** amount.

The ***solvent*** is the substance present in the **larger** amount.

Solution	Solvent	Solute
Air (*g*)	N_2	O_2, Ar, CH_4
Soft drink (*l*)	H_2O	Sugar, CO_2
Soft Solder (*s*)	Pb	Sn

aqueous solutions of $KMnO_4$

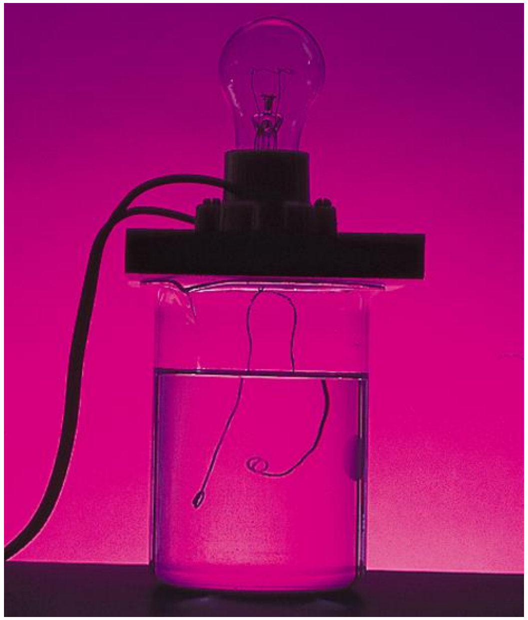
Solution, Solute & Solvent

- So, a solution may be:
  - gaseous (such as air)
  - liquid (such as seawater)
  - solid (such as an alloy)
- Here we will discuss only ***aqueous solution***
  - in which *the solute is a **solid** or **liquid,** and the sovent is **water***
- All solute that dissolve in water fit into ***two*** types*:*
  - ***Electrolyte and Nonelectrolyte***
- Electrolytes are of ***two*** categories:
  - ***Strong electrolyte and Weak electrolyte***

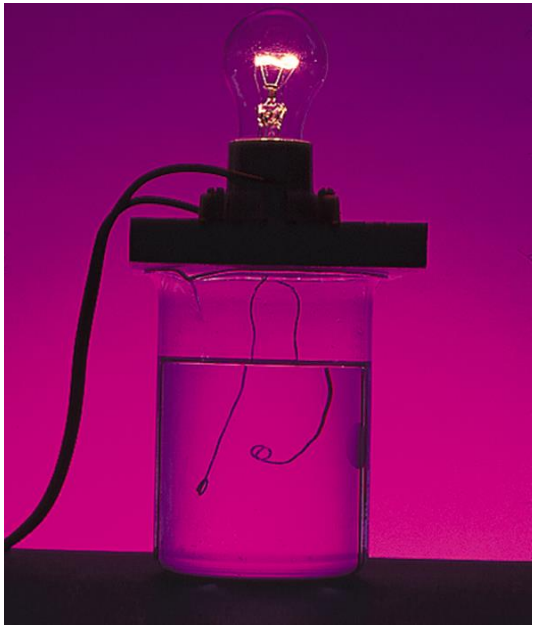
Electrolyte & Nonelectrolyte

An ***electrolyte*** is a substance that, when dissolved in water, results in a solution that can conduct electricity.

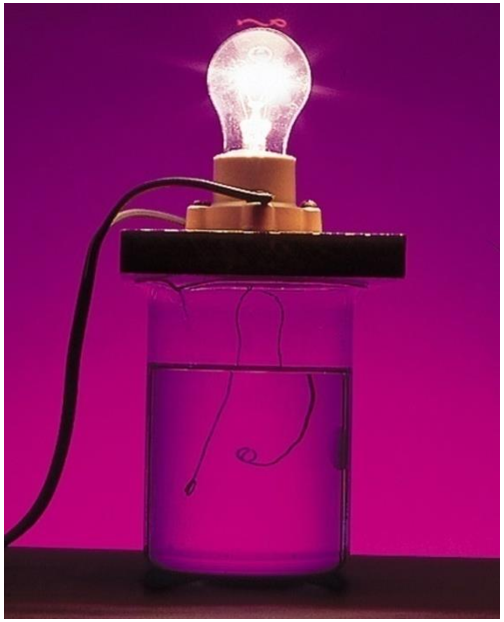
A ***nonelectrolyte*** is a substance that, when dissolved, results in a solution that does not conduct electricity.



nonelectrolyte



weak electrolyte



strong electrolyte

Electrolyte & Nonelectrolyte

Conduct electricity in solution?

Cations (+) and Anions (-)

Strong Electrolyte – 100% dissociation

$$NaCl\ (s) \xrightarrow{H_2O} Na^+\ (aq) + Cl^-\ (aq)$$

Weak Electrolyte – not completely dissociated

$$CH_3COOH \rightleftharpoons CH_3COO^-\ (aq) + H^+\ (aq)$$

Electrolyte & Nonelectrolyte

Ionization of acetic acid

$$CH_3COOH \rightleftharpoons CH_3COO^- (aq) + H^+ (aq)$$

$\rightleftharpoons$ A ***reversible*** reaction. The reaction can occur in both directions.

Reaches an ***equilibrium*****.**

Acetic acid is a ***weak electrolyte*** because its ionization in water is incomplete.

Electrolyte & Nonelectrolyte

Nonelectrolyte does not conduct electricity?

No cations (+) and anions (-) in solution

$$C_6H_{12}O_6\ (s) \xrightarrow{H_2O} C_6H_{12}O_6\ (aq)$$

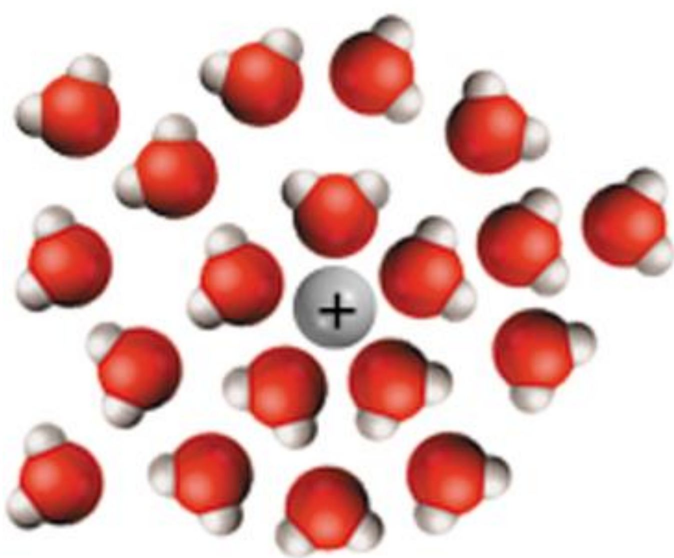
TABLE 4.1 Classification of Solutes in Aqueous Solution

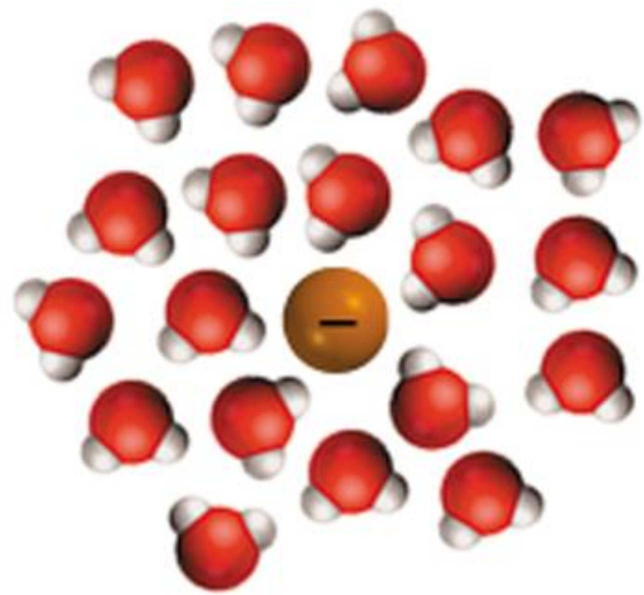
Strong Electrolyte	Weak Electrolyte	Nonelectrolyte
HCl	CH_3COOH	$(NH_2)_2CO$ (urea)
HNO_3	HF	CH_3OH (methanol)
$HClO_4$	HNO_2	C_2H_5OH (ethanol)
H_2SO_4*	NH_3	$C_6H_{12}O_6$ (glucose)
NaOH	H_2O†	$C_{12}H_{22}O_{11}$ (sucrose)
$Ba(OH)_2$		
Ionic compounds		

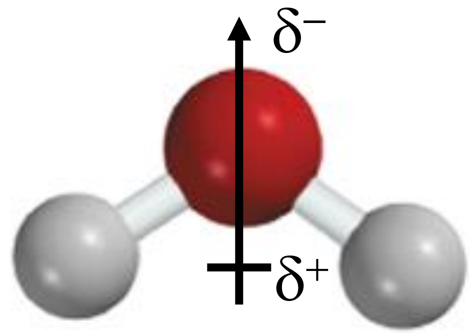
*H_2SO_4 has two ionizable H^+ ions.
†Pure water is an extremely weak electrolyte.

Solution Process

Hydration is the process in which an ion is surrounded by water molecules arranged in a specific manner.



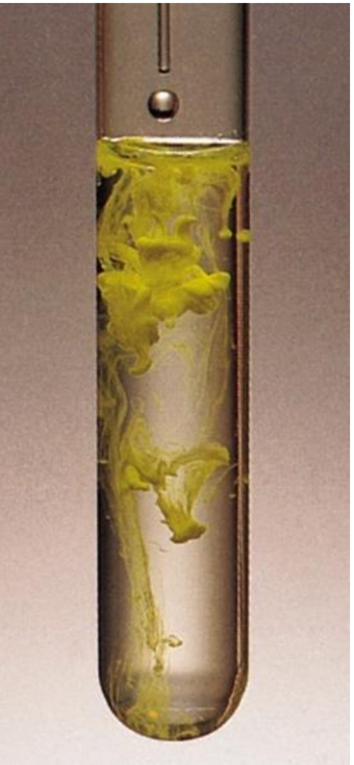




H_2O

Precipitation Reactions

Precipitate – insoluble solid that separates from solution



PbI_2

precipitate

$$Pb(NO_3)_2\ (aq) + 2NaI\ (aq) \longrightarrow PbI_2\ (s) + 2NaNO_3\ (aq)$$

molecular equation

$$Pb^{2+} + \cancel{2NO_3^-} + \cancel{2Na^+} + 2I^- \longrightarrow PbI_2\ (s) + \cancel{2Na^+} + \cancel{2NO_3^-}$$

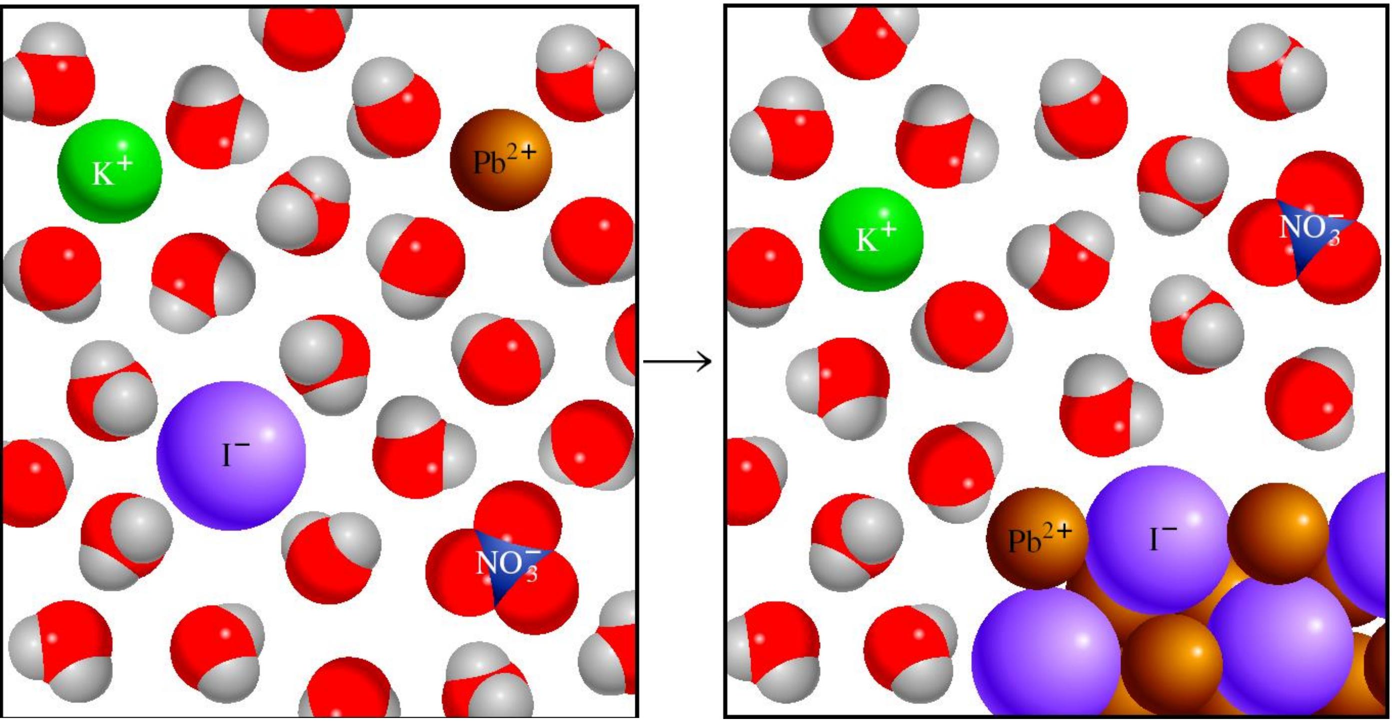
ionic equation

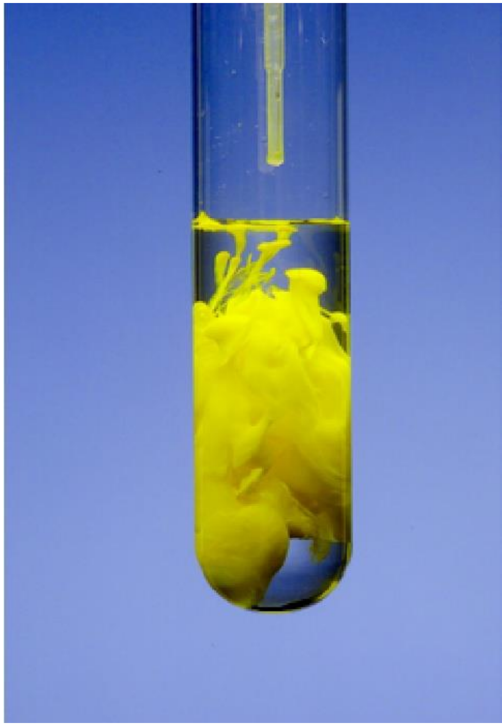
$$Pb^{2+} + 2I^- \longrightarrow PbI_2\ (s)$$

net ionic equation

Na^+ and NO_3^- are ***spectator*** ions

Precipitation of Lead Iodide





$Pb^{2+} + 2I^{-} \longrightarrow PbI_2\ (s)$

PbI_2

Predicting Precipitation

How can we predict whether a precipitate will form?

It depends on the **solubility** of the solute.

Solubility is the maximum amount of solute that will dissolve in a given quantity of solvent at a specific temperature.

Substances can be

- Soluble
- Slightly soluble
- Insoluble

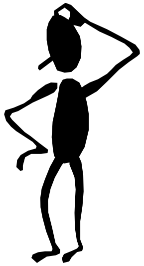
All ionic compounds are strong electrolytes, but not equally soluble.

Solubility Rules

TABLE 4.2 Solubility Rules for Common Ionic Compounds in Water at 25°C

Soluble Compounds	Insoluble Exceptions
Compounds containing alkali metal ions (Li^+, Na^+, K^+, Rb^+, Cs^+) and the ammonium ion (NH_4^+)	
Nitrates (NO_3^-), bicarbonates (HCO_3^-), and chlorates (ClO_3^-)	
Halides (Cl^-, Br^-, I^-)	Halides of Ag^+, Hg_2^{2+}, and Pb^{2+}
Sulfates (SO_4^{2-})	Sulfates of Ag^+, Ca^{2+}, Sr^{2+}, Ba^{2+}, Hg_2^{2+}, and Pb^{2+}

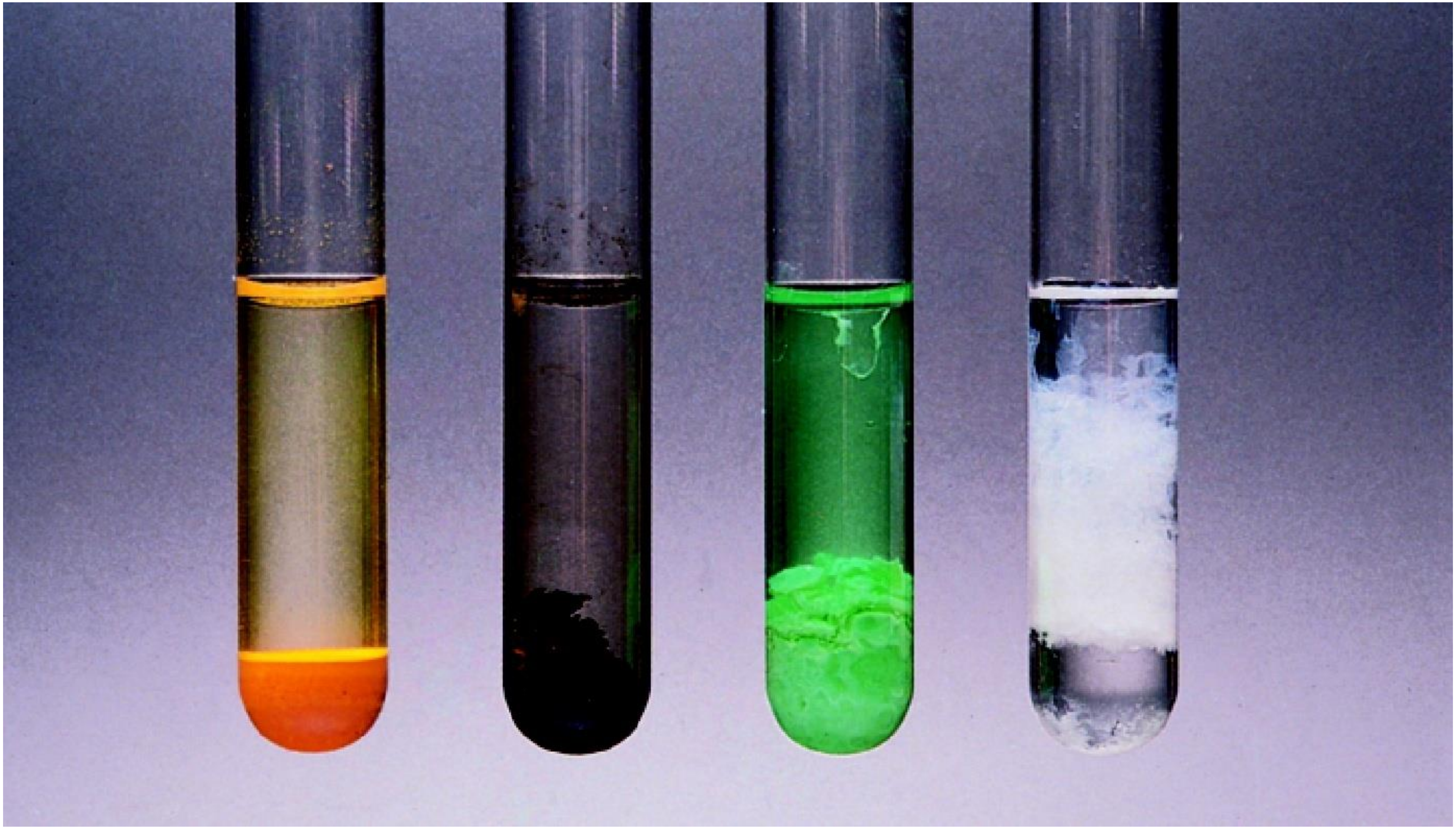
Insoluble Compounds	Soluble Exceptions
Carbonates (CO_3^{2-}), phosphates (PO_4^{3-}), chromates (CrO_4^{2-}), sulfides (S^{2-})	Compounds containing alkali metal ions and the ammonium ion
Hydroxides (OH^-)	Compounds containing alkali metal ions and the Ba^{2+} ion



Identify each of the following species as a soluble or insoluble:

Siver sulfate, Ag_2SO_4	Insoluble
Calcium carbonate, $CaCO_3$	Insoluble
Sodium phosphate, Na_3PO_4	Soluble
Copper sulfide, CuS	Insoluble
Calcium hydroxide, $Ca(OH)_2$	Insoluble
Zinc nitrate, $Zn(NO_3)_2$	Soluble

Examples of Insoluble Compounds



CdS PbS $Ni(OH)_2$ $Al(OH)_3$

Writing Net Ionic Equations

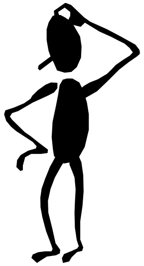
1. Write the balanced molecular equation.
2. Write the ionic equation showing the strong electrolytes completely dissociated into cations and anions.
3. Cancel the spectator ions on both sides of the ionic equation
4. Check that charges and number of atoms are balanced in the net ionic equation

Write the net ionic equation for the reaction of silver nitrate with sodium chloride.

$$AgNO_3(aq) + NaCl(aq) \longrightarrow AgCl(s) + NaNO_3(aq)$$

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

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



Predict what happens when a potassium phosphate K_3PO_4 solution is mixed with a strontium nitrate $Sr(NO_3)_2$ solution. Write the ionic and net ionic equation for the reaction.

$$2K_3PO_4(aq) + 3Sr(NO_3)_2(aq)$$
$$\rightarrow Sr_3(PO_4)_2(s) + 6KNO_3(aq)$$

Ionic:

$$\cancel{6K^{+}}(aq) + 2PO_4^{3-}(aq) + 3Sr^{2+}(aq) + \cancel{6NO_3^{-}}(aq)$$
$$\rightarrow Sr_3(PO_4)_2(s) + \cancel{6K^{+}}(aq) + \cancel{6NO_3^{-}}(aq)$$

Net ionic:

$$3Sr_2^{+}(aq) + 2PO_4^{3-}(aq) \rightarrow Sr_3(PO_4)_2(s)$$

Acid-Base Reactions

Properties of Acids

- Have a sour taste. Vinegar owes its taste to acetic acid. Citrus fruits contain citric acid.
- Cause color changes in plant dyes.
- React with certain metals to produce hydrogen gas.

$$2HCl(aq) + Mg(s) \longrightarrow MgCl_2(aq) + H_2(g)$$

- React with carbonates and bicarbonates to produce carbon dioxide gas

$$2HCl(aq) + CaCO_3(s) \longrightarrow CaCl_2(aq) + CO_2(g) + H_2O(l)$$

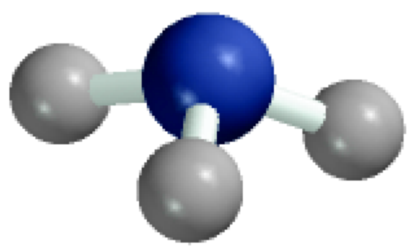
- Aqueous acid solutions conduct electricity.

Acid-Base Reactions

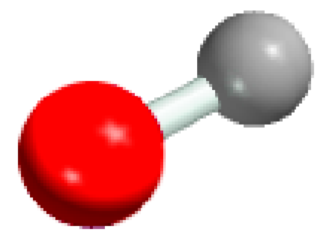
Properties of Bases

- Have a bitter taste.
- Feel slippery. Many soaps contain bases.
- Cause color changes in plant dyes.
- Aqueous base solutions conduct electricity.

Examples:



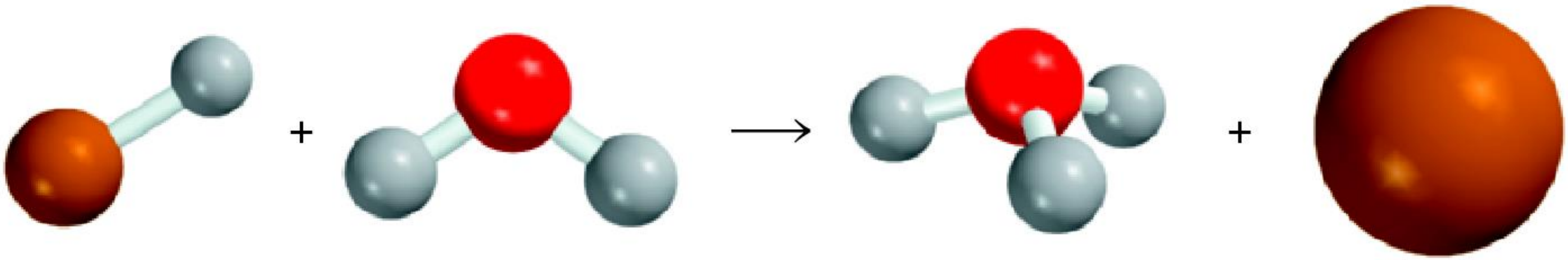
NH_3



OH^-

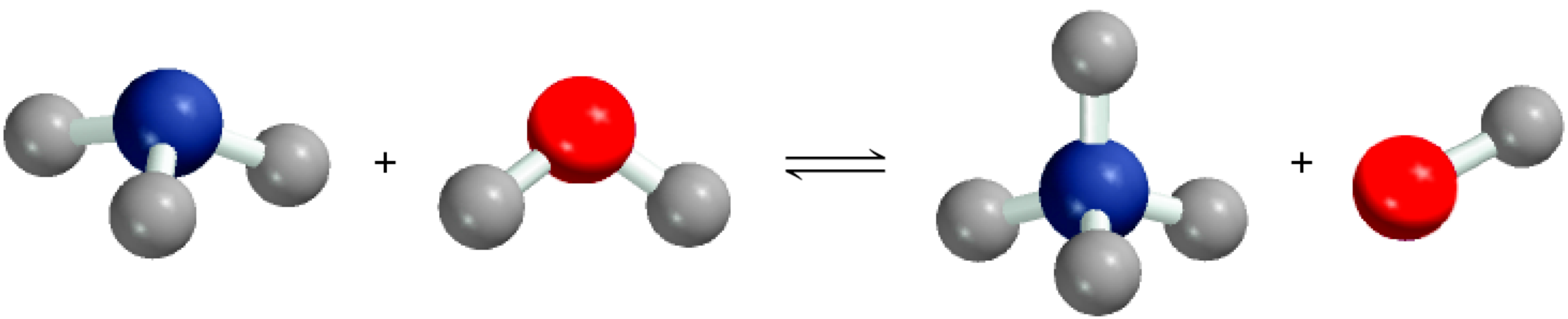
Arrhenius Acid & Base

Arrhenius acid is a substance that produces H^+ (H_3O^+) in water.



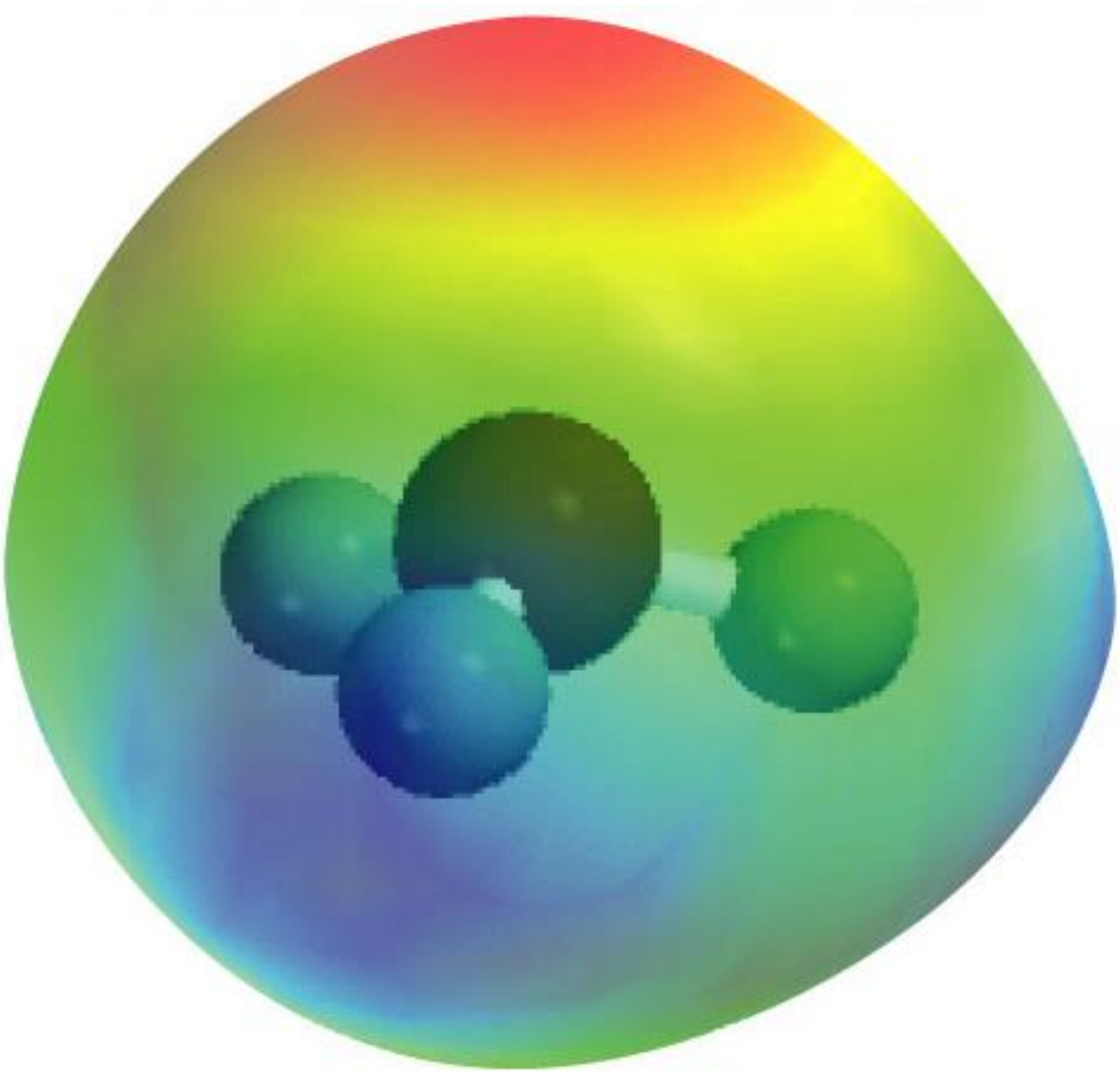
$$HCl + H_2O \longrightarrow H_3O^+ + Cl^-$$

Arrhenius base is a substance that produces OH^- in water.



$$NH_3 + H_2O \rightleftharpoons NH_4^+ + OH^-$$

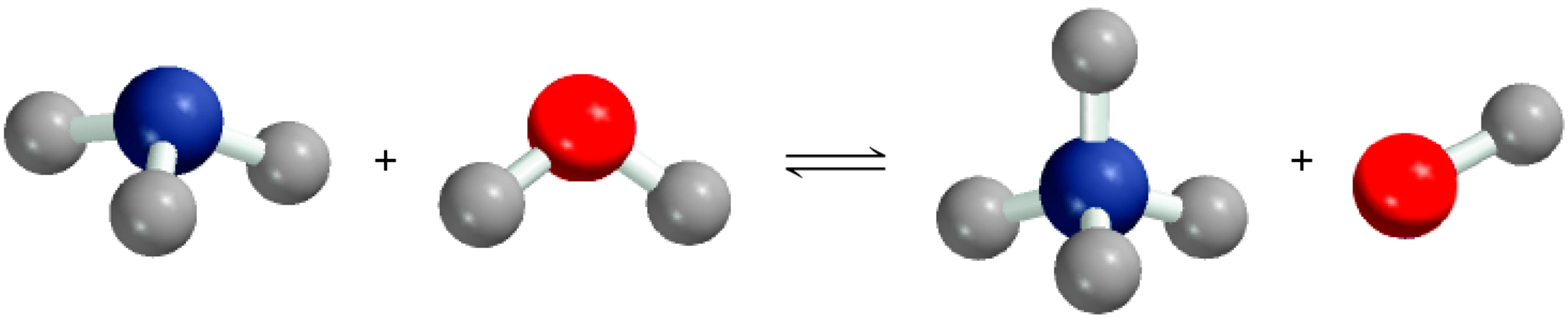
Hydronium ion, hydrated proton, H_3O^+



Brønsted Acid & Base

A ***Brønsted*** ***acid*** is a proton donor.

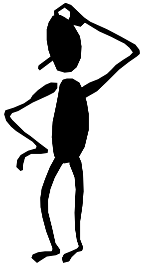
A ***Brønsted*** ***base*** is a proton acceptor.



$$NH_3 + H_2O \rightleftharpoons NH_4^+ + OH^-$$

base acid acid base

A Brønsted acid must contain at least one ionizable proton!



Identify each of the following as a Brønsted acid, base, or both. (a) HI, (b) CH_3COO^-, (c) $H_2PO_4^-$, (d) HSO_4^-

$HI\ (aq) \longrightarrow H^+\ (aq) + I^-\ (aq)$ Brønsted acid

$CH_3COO^-\ (aq) + H^+\ (aq) \rightleftharpoons CH_3COOH\ (aq)$ Brønsted base

$H_2PO_4^-\ (aq) \rightleftharpoons H^+\ (aq) + HPO_4^{2-}\ (aq)$ Brønsted acid

$H_2PO_4^-\ (aq) + H^+\ (aq) \rightleftharpoons H_3PO_4\ (aq)$ Brønsted base

$HSO_4^-\ (aq) \rightleftharpoons H^+\ (aq) + SO_4^{2-}\ (aq)$ Brønsted acid

$HSO_4^-\ (aq) + H^+\ (aq) \rightleftharpoons H_2SO_4\ (aq)$ Brønsted base

Mono-, Di- & Triprotic Acids

Monoprotic acids

$HCl \longrightarrow H^+ + Cl^-$ Strong electrolyte, strong acid

$HNO_3 \longrightarrow H^+ + NO_3^-$ Strong electrolyte, strong acid

$CH_3COOH \rightleftharpoons H^+ + CH_3COO^-$ Weak electrolyte, weak acid

Diprotic acids

$H_2SO_4 \longrightarrow H^+ + HSO_4^-$ Strong electrolyte, strong acid

$HSO_4^- \rightleftharpoons H^+ + SO_4^{2-}$ Weak electrolyte, weak acid

Triprotic acids

$H_3PO_4 \rightleftharpoons H^+ + H_2PO_4^-$ Weak electrolyte, weak acid

$H_2PO_4^- \rightleftharpoons H^+ + HPO_4^{2-}$ Weak electrolyte, weak acid

$HPO_4^{2-} \rightleftharpoons H^+ + PO_4^{3-}$ Weak electrolyte, weak acid

TABLE 4.3

Some Common Strong and Weak Acids

Strong Acids	
Hydrochloric acid	HCl
Hydrobromic acid	HBr
Hydroiodic acid	HI
Nitric acid	HNO_3
Sulfuric acid	H_2SO_4
Perchloric acid	$HClO_4$

Weak Acids	
Hydrofluoric acid	HF
Nitrous acid	HNO_2
Phosphoric acid	H_3PO_4
Acetic acid	CH_3COOH

Neutralization Reaction

acid + base $\longrightarrow$ salt + water

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

$$H^+ + \cancel{Cl^-} + \cancel{Na^+} + OH^- \longrightarrow \cancel{Na^+} + \cancel{Cl^-} + H_2O$$

$$H^+ + OH^- \longrightarrow H_2O$$

Neutralization Reaction Involving a Weak Electrolyte

weak acid + base $\longrightarrow$ salt + water

$HCN(aq) + NaOH(aq) \longrightarrow NaCN(aq) + H_2O$

$HCN + \cancel{Na^+} + OH^- \longrightarrow \cancel{Na^+} + CN^- + H_2O$

$HCN + OH^- \longrightarrow CN^- + H_2O$

Neutralization Reaction Producing a Gas

$$\text{acid} + \text{base} \longrightarrow \text{salt} + \text{water} + CO_2$$

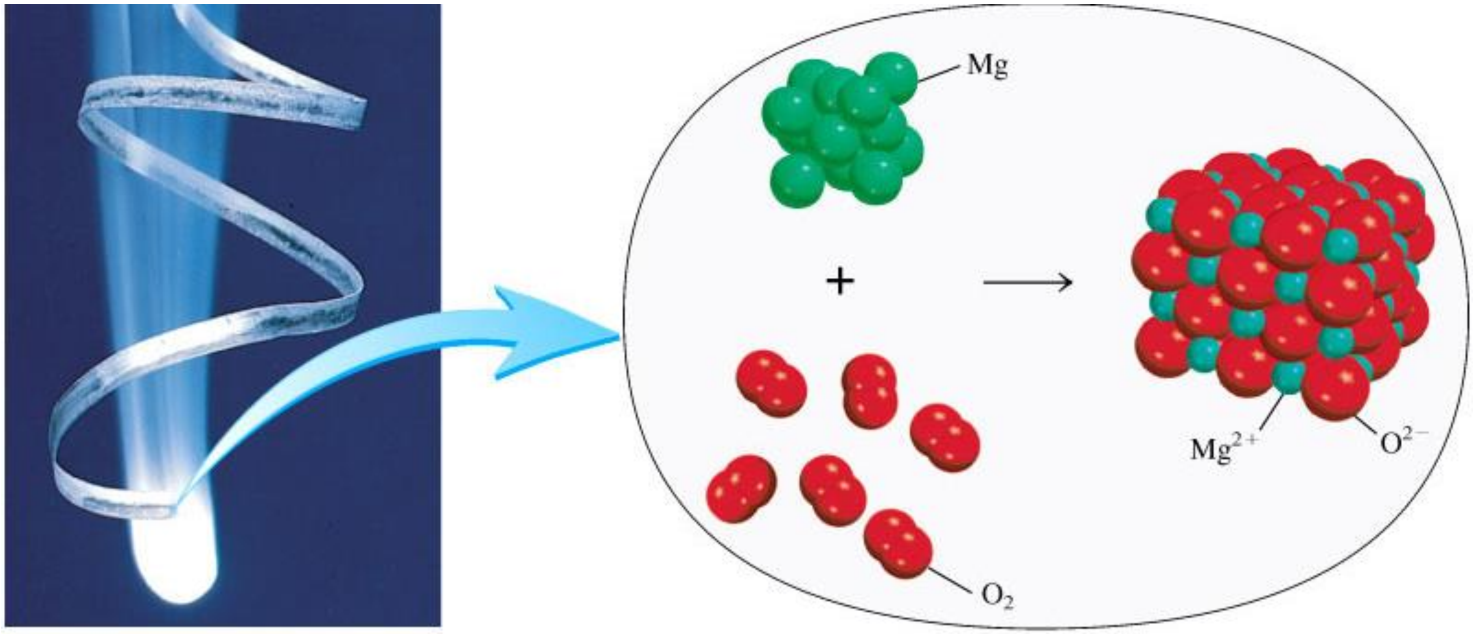
$$2HCl(aq) + Na_2CO_3(aq) \longrightarrow 2NaCl(aq) + H_2O + CO_2$$

$$2H^+ + \cancel{2Cl^-} + \cancel{2Na^+} + CO_3^{2-} \longrightarrow \cancel{2Na^+} + \cancel{2Cl^-} + H_2O + CO_2$$

$$2H^+ + CO_3^{2-} \longrightarrow H_2O + CO_2$$

Oxidation-Reduction Reactions

(electron transfer reactions)



$2Mg \longrightarrow 2Mg^{2+} + 4e^-$ ***Oxidation*** half-reaction (lose e^-)

$O_2 + 4e^- \longrightarrow 2O^{2-}$ ***Reduction*** half-reaction (gain e^-)

$$2Mg + O_2 + \cancel{4e^-} \longrightarrow 2Mg^{2+} + 2O^{2-} + \cancel{4e^-}$$

$$2Mg + O_2 \longrightarrow 2MgO$$

Oxidation-Reduction Reactions

(electron transfer reactions)

OILRIG

Oxidation

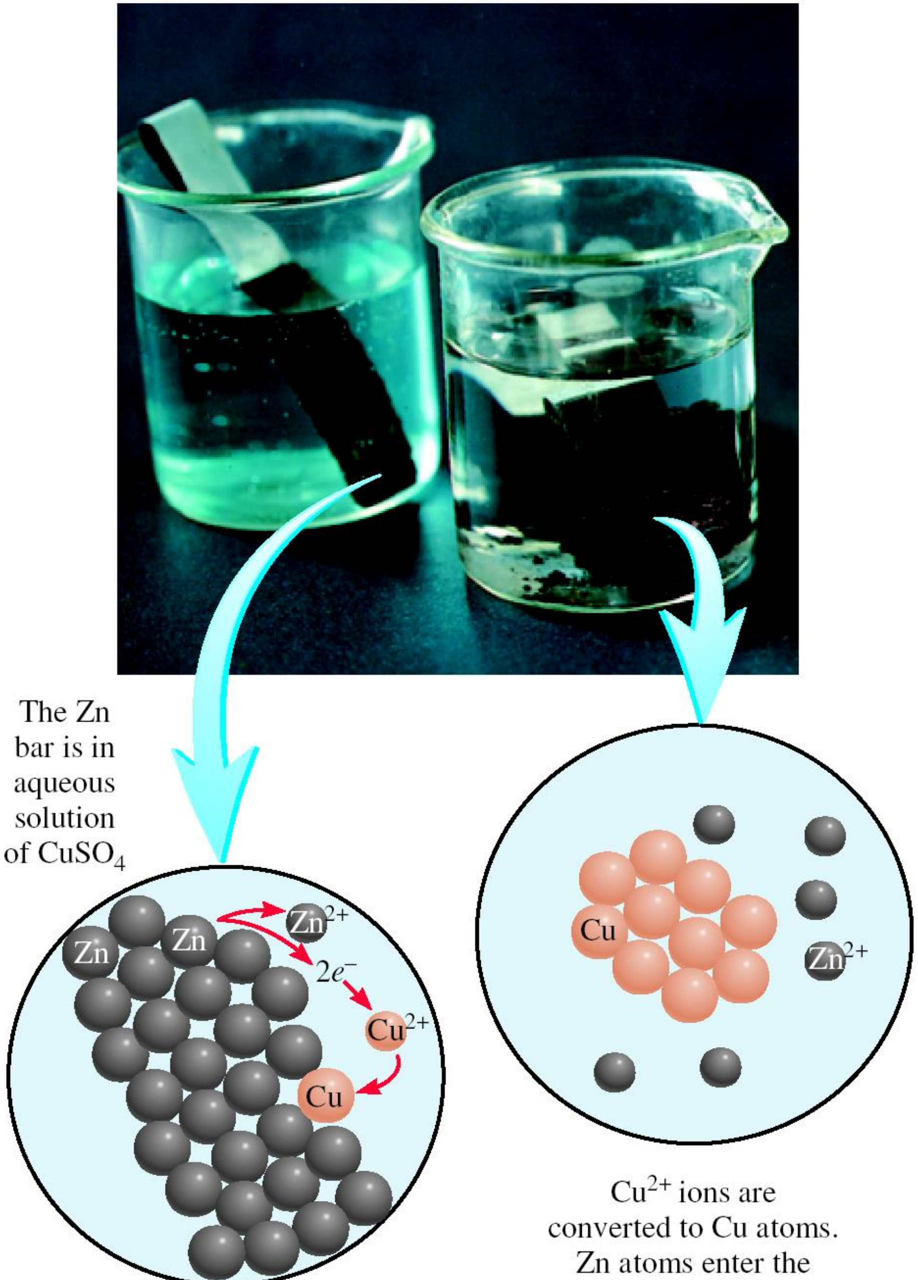
Is

Loss of e^-

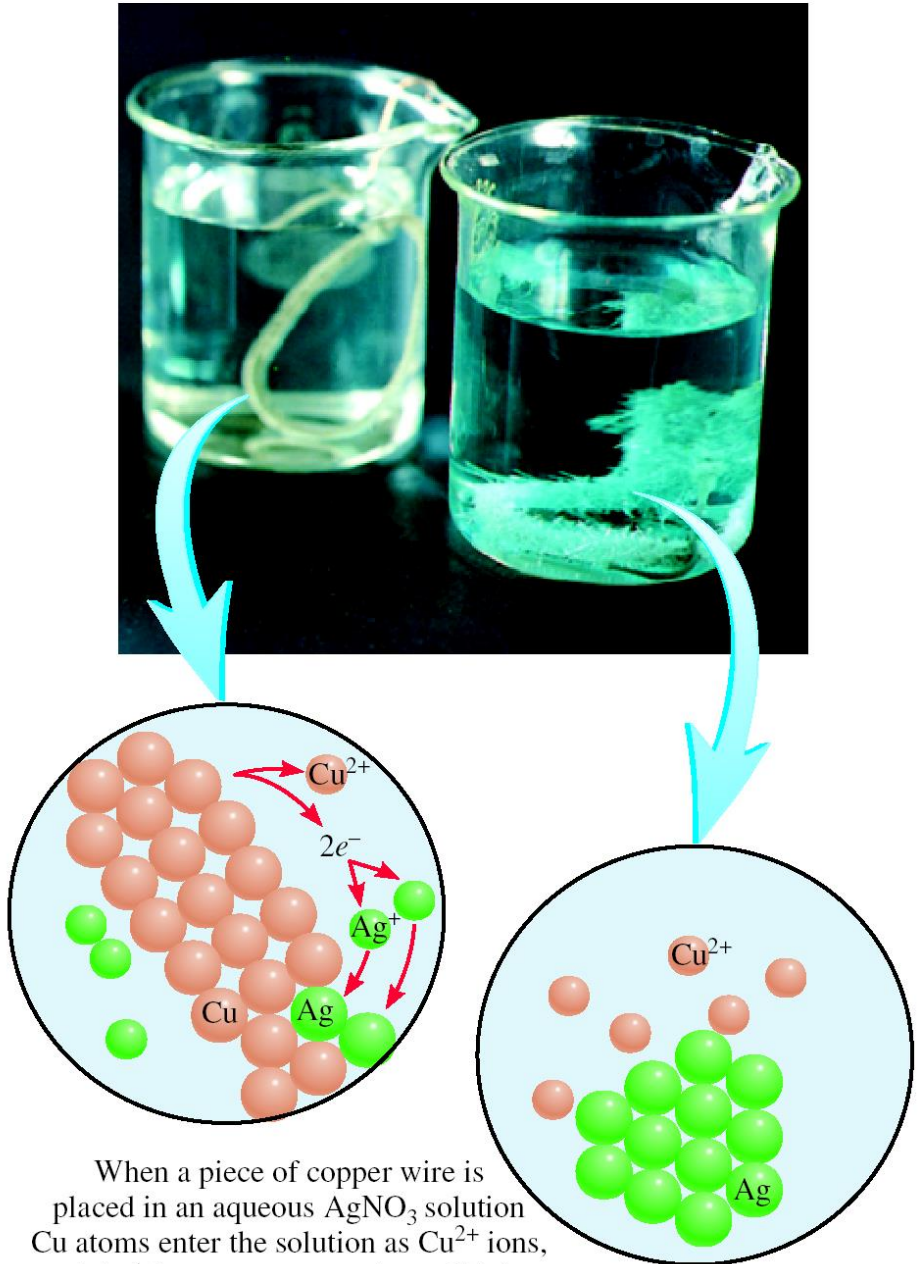
Reduction

Is

Gain of e^-



Cu^{2+} ions are converted to Cu atoms. Zn atoms enter the solution as Zn^{2+} ions.



When a piece of copper wire is placed in an aqueous $AgNO_3$ solution Cu atoms enter the solution as Cu^{2+} ions, and Ag^+ ions are converted to solid Ag.

- Zinc bar reacts with copper(II) sulfate to form copper metal. Write the redox reaction, half-reactions & identify the oxidizing agent, reducing agent.

$$Zn(s) + CuSO_4(aq) \longrightarrow ZnSO_4(aq) + Cu(s)$$

$Zn \longrightarrow Zn^{2+} + 2e^-$ Zn is oxidized Zn is the ***reducing agent***

$Cu^{2+} + 2e^- \longrightarrow Cu$ Cu^{2+} is reduced Cu^{2+} is the ***oxidizing agent***

- Copper wire reacts with silver nitrate to form silver metal. Write the redox reaction, half-reactions & identify the oxidizing agent, reducing agent.

$$Cu(s) + 2AgNO_3(aq) \longrightarrow Cu(NO_3)_2(aq) + 2Ag(s)$$

$Cu \longrightarrow Cu^{2+} + 2e^-$ Cu is oxidized Cu is the ***reducing agent***

$Ag^+ + e^- \longrightarrow Ag$ Ag^+ is reduced Ag^+ is the ***oxidizing agent***

Oxidation number

The charge the atom would have in a molecule (or an ionic compound) if electrons were completely transferred.

1. Free elements (uncombined state) have an oxidation number of zero.

$$Na, Be, K, Pb, H_2, O_2, P_4 = 0$$

2. In monatomic ions, the oxidation number is equal to the charge on the ion.

$$Li^+, Li = +1; Fe^{3+}, Fe = +3; O^{2-}, O = -2$$

3. The oxidation number of oxygen is **usually** –2. In H_2O_2 and O_2^{2-} it is –1.

4. The oxidation number of hydrogen is +1 *except* when it is bonded to metals in binary compounds. In these cases, its oxidation number is –1.
5. Group IA metals are +1, IIA metals are +2 and fluorine is always –1.
6. The sum of the oxidation numbers of all the atoms in a molecule or ion is equal to the charge on the molecule or ion.
7. Oxidation numbers do not have to be integers. Oxidation number of oxygen in the superoxide ion, O_2^-, is –½.

What are the oxidation numbers of all the elements in HCO_3^- ?

HCO_3^-

O = –2 H = +1

$$\boxed{3x(-2) + 1 + ? = -1}$$

C = +4

The Oxidation Numbers of Elements in their Compounds

1 1A	2 2A	3 3B	4 4B	5 5B	6 6B	7 7B	8 8B	9 8B	10 8B	11 1B	12 2B	13 3A	14 4A	15 5A	16 6A	17 7A	18 8A
1 **H** +1 −1																	2 **He**
3 **Li** +1	4 **Be** +2											5 **B** +3	6 **C** +4 +2 −4	7 **N** +5 +4 +3 +2 +1 −3	8 **O** +2 $-\frac{1}{2}$ −1 −2	9 **F** −1	10 **Ne**
11 **Na** +1	12 **Mg** +2											13 **Al** +3	14 **Si** +4 −4	15 **P** +5 +3 −3	16 **S** +6 +4 +2 −2	17 **Cl** +7 +6 +5 +4 +3 +1 −1	18 **Ar**
19 **K** +1	20 **Ca** +2	21 **Sc** +3	22 **Ti** +4 +3 +2	23 **V** +5 +4 +3 +2	24 **Cr** +6 +5 +4 +3 +2	25 **Mn** +7 +6 +4 +3 +2	26 **Fe** +3 +2	27 **Co** +3 +2	28 **Ni** +2	29 **Cu** +2 +1	30 **Zn** +2	31 **Ga** +3	32 **Ge** +4 −4	33 **As** +5 +3 −3	34 **Se** +6 +4 −2	35 **Br** +5 +3 +1 −1	36 **Kr** +4 +2
37 **Rb** +1	38 **Sr** +2	39 **Y** +3	40 **Zr** +4	41 **Nb** +5 +4	42 **Mo** +6 +4 +3	43 **Tc** +7 +6 +4	44 **Ru** +8 +6 +4 +3	45 **Rh** +4 +3 +2	46 **Pd** +4 +2	47 **Ag** +1	48 **Cd** +2	49 **In** +3	50 **Sn** +4 +2	51 **Sb** +5 +3 −3	52 **Te** +6 +4 −2	53 **I** +7 +5 +1 −1	54 **Xe** +6 +4 +2
55 **Cs** +1	56 **Ba** +2	57 **La** +3	72 **Hf** +4	73 **Ta** +5	74 **W** +6 +4	75 **Re** +7 +6 +4	76 **Os** +8 +4	77 **Ir** +4 +3	78 **Pt** +4 +2	79 **Au** +3 +1	80 **Hg** +2 +1	81 **Tl** +3 +1	82 **Pb** +4 +2	83 **Bi** +5 +3	84 **Po** +2	85 **At** −1	86 **Rn**

What are the oxidation numbers of all the elements in each of these compounds?

$NaIO_3$ IF_7 $K_2Cr_2O_7$

$NaIO_3$

Na = +1 O = -2

3x(-2) + 1 + ? = 0

I = +5

IF_7

F = -1

7x(-1) + ? = 0

I = +7

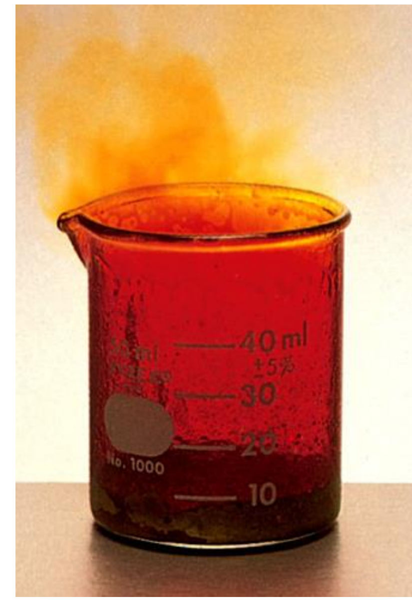
$K_2Cr_2O_7$

O = -2 K = +1

7x(-2) + 2x(+1) + 2x(?) = 0

Cr = +6

Types of Oxidation-Reduction Reactions



Combination Reaction

$$A + B \longrightarrow C$$

$$2\overset{0}{Al} + 3\overset{0}{Br_2} \longrightarrow 2\overset{+3}{Al}\overset{-1}{Br_3}$$

Decomposition Reaction

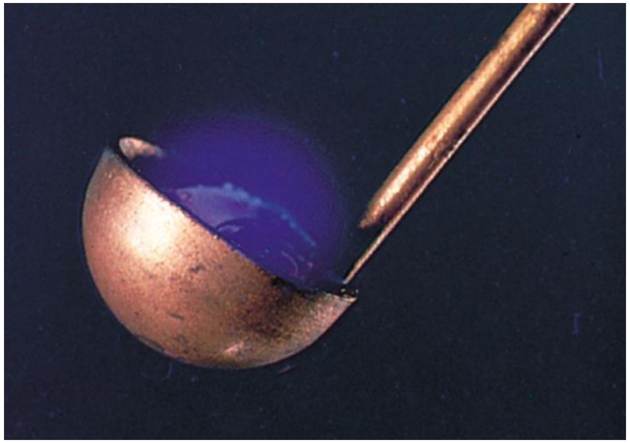
$$C \longrightarrow A + B$$

$$2\overset{+1}{K}\overset{+5}{Cl}\overset{-2}{O_3} \longrightarrow 2\overset{+1}{K}\overset{-1}{Cl} + 3\overset{0}{O_2}$$

Types of Oxidation-Reduction Reactions

Combustion Reaction

$$A + O_2 \longrightarrow B$$



$$\overset{0}{S} + \overset{0}{O_2} \longrightarrow \overset{+4}{S}\overset{-2}{O_2}$$

$$2\overset{0}{Mg} + \overset{0}{O_2} \longrightarrow 2\overset{+2}{Mg}\overset{-2}{O}$$

Types of Oxidation-Reduction Reactions

Displacement Reaction

$$A + BC \longrightarrow AC + B$$

$$\overset{0}{Sr} + 2\overset{+1}{H_2}O \longrightarrow \overset{+2}{Sr}(OH)_2 + \overset{0}{H_2}$$ Hydrogen Displacement

$$\overset{+4}{Ti}Cl_4 + 2\overset{0}{Mg} \longrightarrow \overset{0}{Ti} + 2\overset{+2}{Mg}Cl_2$$ Metal Displacement

$$\overset{0}{Cl_2} + 2K\overset{-1}{Br} \longrightarrow 2K\overset{-1}{Cl} + \overset{0}{Br_2}$$ Halogen Displacement

The Activity Series for Metals

Reducing strength increases

$Li \rightarrow Li^{+} + e^{-}$	React with cold water to produce H_2
$K \rightarrow K^{+} + e^{-}$	
$Ba \rightarrow Ba^{2+} + 2e^{-}$	
$Ca \rightarrow Ca^{2+} + 2e^{-}$	
$Na \rightarrow Na^{+} + e^{-}$	
$Mg \rightarrow Mg^{2+} + 2e^{-}$	React with steam to produce H_2
$Al \rightarrow Al^{3+} + 3e^{-}$	
$Zn \rightarrow Zn^{2+} + 2e^{-}$	
$Cr \rightarrow Cr^{3+} + 3e^{-}$	
$Fe \rightarrow Fe^{2+} + 2e^{-}$	
$Cd \rightarrow Cd^{2+} + 2e^{-}$	
$Co \rightarrow Co^{2+} + 2e^{-}$	React with acids to produce H_2
$Ni \rightarrow Ni^{2+} + 2e^{-}$	
$Sn \rightarrow Sn^{2+} + 2e^{-}$	
$Pb \rightarrow Pb^{2+} + 2e^{-}$	
$H_2 \rightarrow 2H^{+} + 2e^{-}$	
$Cu \rightarrow Cu^{2+} + 2e^{-}$	Do not react with water or acids to produce H_2
$Ag \rightarrow Ag^{+} + e^{-}$	
$Hg \rightarrow Hg^{2+} + 2e^{-}$	
$Pt \rightarrow Pt^{2+} + 2e^{-}$	
$Au \rightarrow Au^{3+} + 3e^{-}$	

Hydrogen Displacement Reaction

$$M + BC \longrightarrow MC + B$$

M is metal

BC is acid or H_2O

B is H_2

$$Ca + 2H_2O \longrightarrow Ca(OH)_2 + H_2$$

$$\cancel{Pb + 2H_2O \longrightarrow Pb(OH)_2 + H_2}$$

The Activity Series for Halogens

$$F_2 > Cl_2 > Br_2 > I_2$$

<u>Halogen Displacement Reaction</u>

$$\overset{0}{Cl_2} + 2K\overset{-1}{Br} \longrightarrow 2K\overset{-1}{Cl} + \overset{0}{Br_2}$$

$$\cancel{I_2 + 2KBr \longrightarrow 2KI + Br_2}$$

Types of Oxidation-Reduction Reactions

<u>Disproportionation Reaction</u>

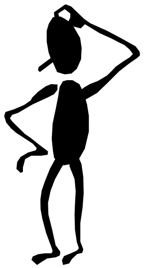
The same element is simultaneously oxidized and reduced.

Example:

reduced

$$\overset{0}{Cl_2} + 2OH^- \longrightarrow \overset{+1}{ClO^-} + \overset{-1}{Cl^-} + H_2O$$

oxidized



Classify each of the following reactions.

$Ca^{2+} + CO_3^{2-} \longrightarrow CaCO_3$ Precipitation

$NH_3 + H^+ \longrightarrow NH_4^+$ Acid-Base

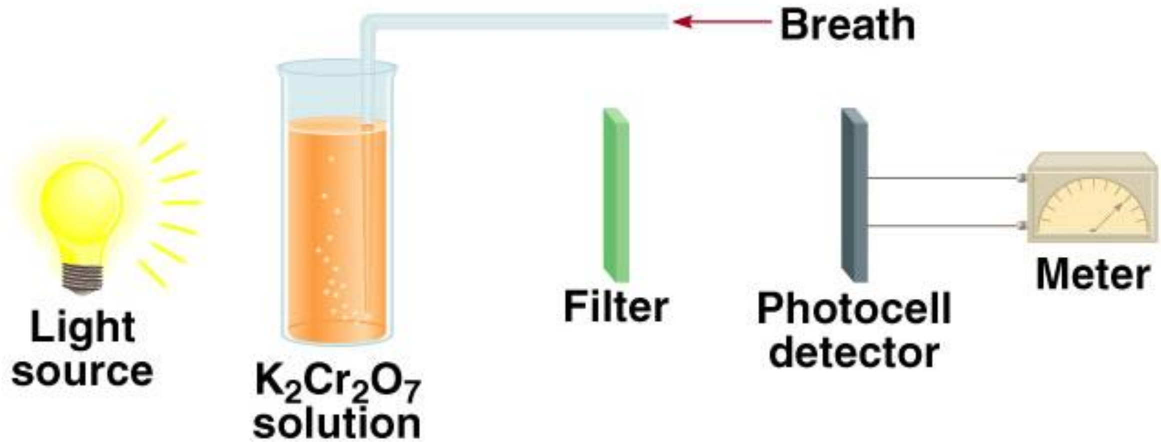
$Zn + 2HCl \longrightarrow ZnCl_2 + H_2$ Redox (H_2 Displacement)

$Ca + F_2 \longrightarrow CaF_2$ Redox (Combination)

Chemistry in Action: Breath Analyzer

$$\overset{}{}3CH_3CH_2OH + 2K_2\overset{+6}{Cr_2}O_7 + 8H_2SO_4 \longrightarrow$$

$$3CH_3COOH + 2\overset{+3}{Cr_2}(SO_4)_3 + 2K_2SO_4 + 11H_2O$$



Solution Stoichiometry

The ***concentration*** of a solution is the amount of solute present in a given quantity of solvent or solution.

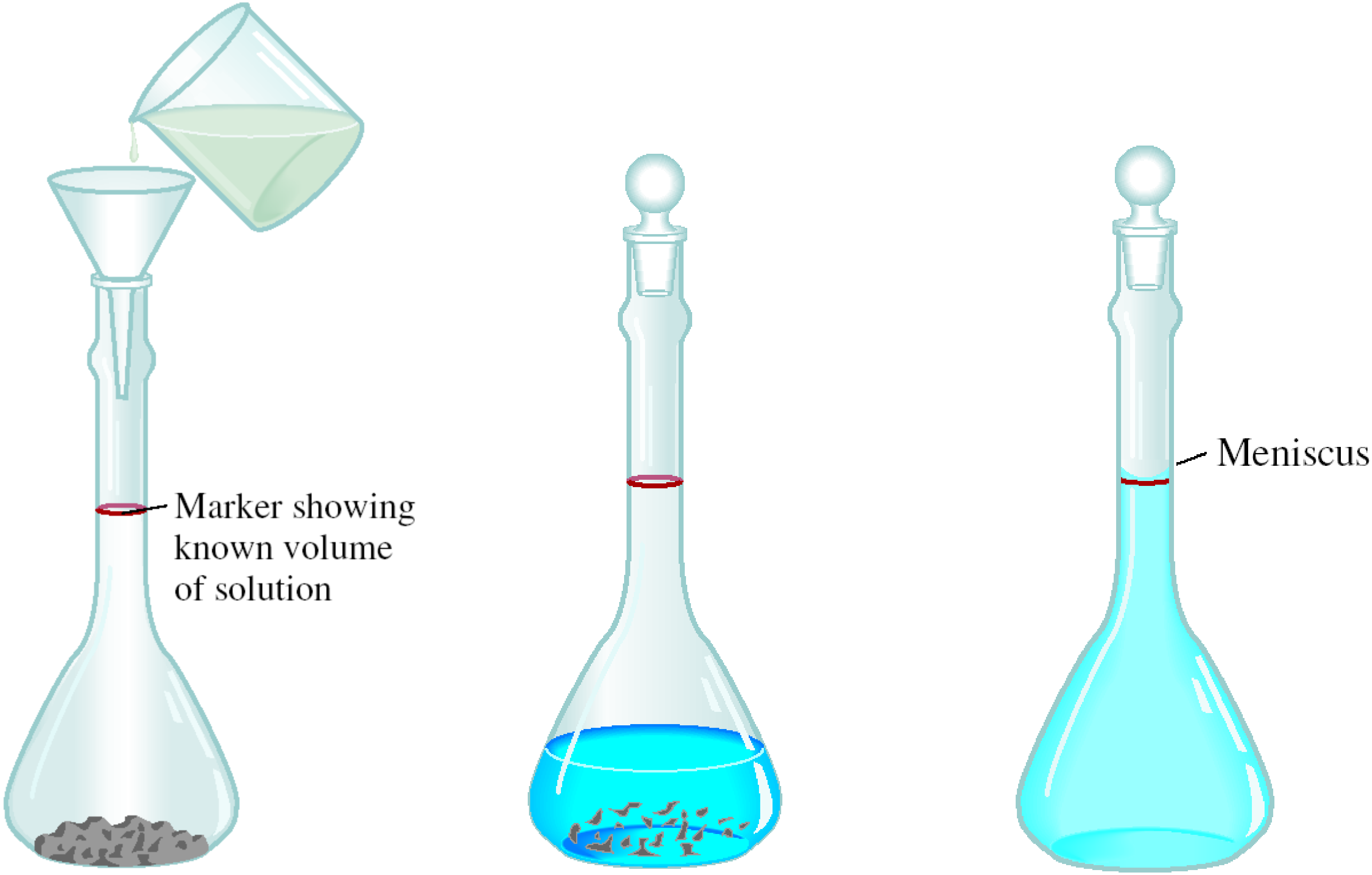
$$\boldsymbol{M = molarity} = \frac{\text{moles of solute}}{\text{liters of solution}}$$

What mass of KI is required to make 500.0 mL of a 2.80 *M* KI solution?

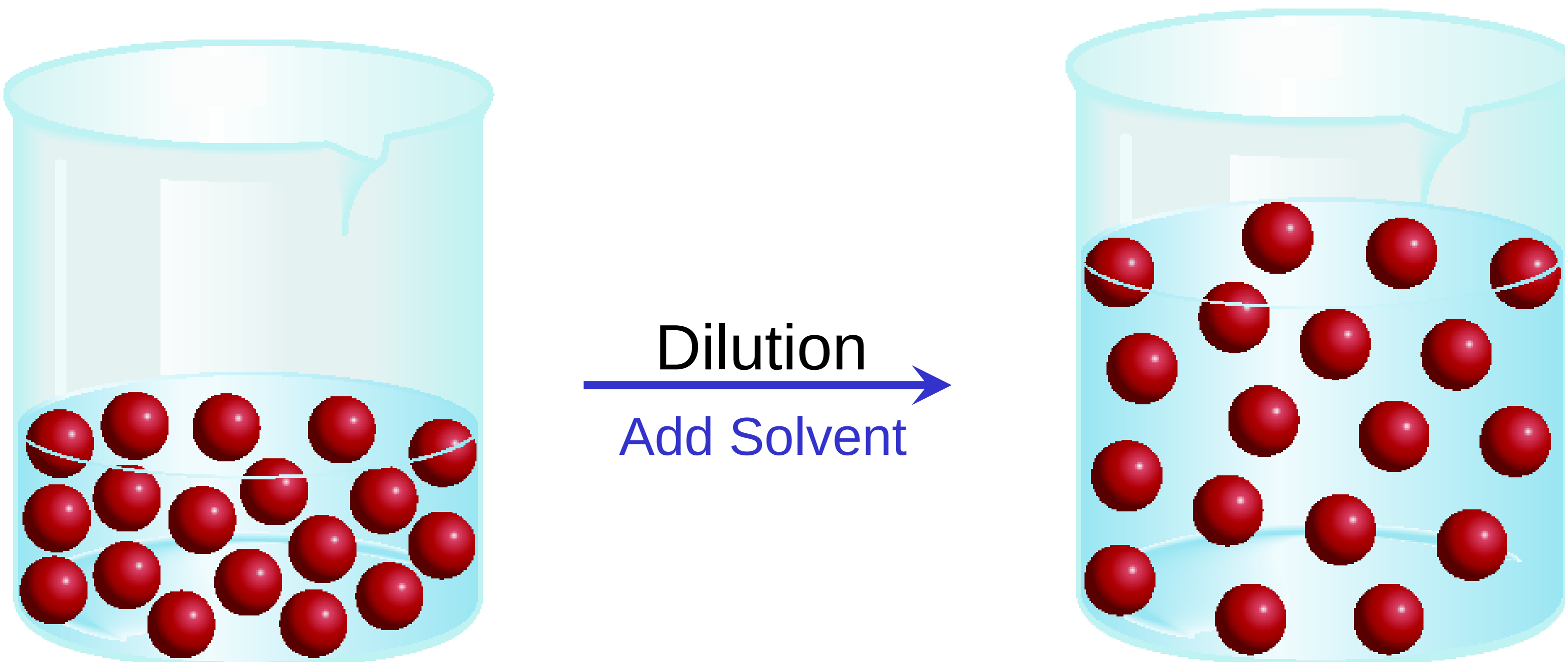
$$\text{volume of KI solution} \xrightarrow{M\ \text{KI}} \text{moles KI} \xrightarrow{\mathcal{M}\ \text{KI}} \text{grams KI}$$

$$500.0\ \cancel{\text{mL}} \times \frac{1\ \cancel{\text{L}}}{1000\ \cancel{\text{mL}}} \times \frac{2.80\ \cancel{\text{mol}}\ \text{KI}}{1\ \cancel{\text{L}}\ \text{soln}} \times \frac{166\ \text{g KI}}{1\ \cancel{\text{mol}}\ \text{KI}} = 232\ \text{g KI}$$

Preparing a Solution of Known Concentration



Dilution is the procedure for preparing a less concentrated solution from a more concentrated solution.



Moles of solute before dilution (i) = Moles of solute after dilution (f)

$$M_i V_i = M_f V_f$$

How would you prepare 60.0 mL of 0.200 *M* HNO_3 from a stock solution of 4.00 *M* HNO_3?

$$M_i V_i = M_f V_f$$

$M_i = 4.00\ M$ $M_f = 0.200\ M$ $V_f = 0.0600\ L$ $V_i = ?\ L$

$$V_i = \frac{M_f V_f}{M_i} = \frac{0.200\ M \times 0.0600\ L}{4.00\ M} = 0.00300\ L = 3.00\ mL$$

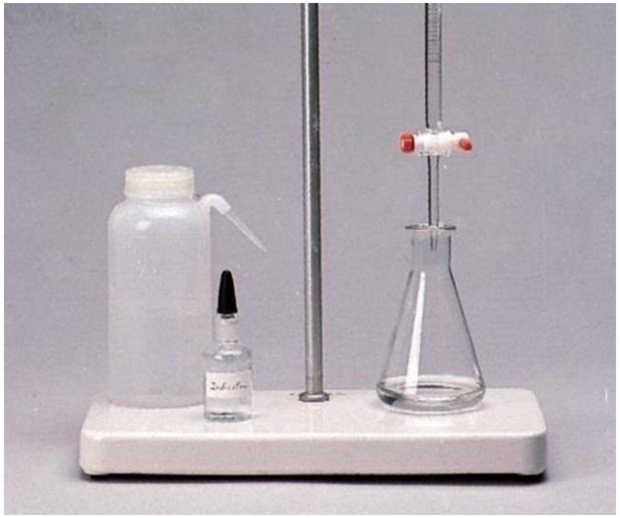
Dilute 3.00 mL of acid with water to a total volume of 60.0 mL.

Titrations

In a ***titration*** a solution of accurately known concentration is added gradually to another solution of unknown concentration until the chemical reaction between the two solutions is complete.

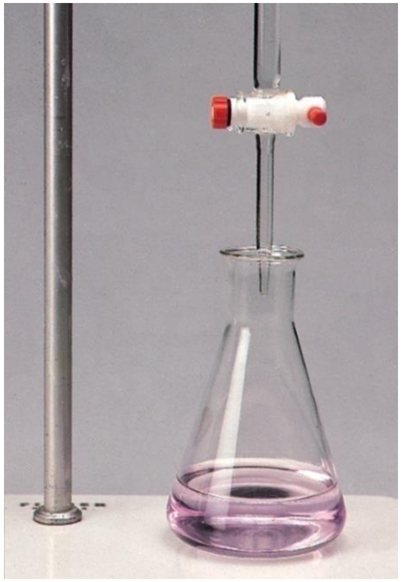
Equivalence point – the point at which the reaction is complete

Indicator – substance that changes color at (or near) the equivalence point



Slowly add base to unknown acid UNTIL

the indicator changes color



What volume of a 1.420 *M* NaOH solution is required to titrate 25.00 mL of a 4.50 *M* H_2SO_4 solution?

WRITE THE CHEMICAL EQUATION!

$$H_2SO_4 + 2NaOH \longrightarrow 2H_2O + Na_2SO_4$$

$$\text{volume acid} \xrightarrow[\text{acid}]{M} \text{moles reqd} \xrightarrow[\text{coef.}]{\text{rxn}} \text{moles base} \xrightarrow[\text{base}]{M} \text{volume base}$$

$$25.00\ \cancel{\text{mL}} \times \frac{4.50\ \cancel{\text{mol } H_2SO_4}}{1000\ \cancel{\text{mL soln}}} \times \frac{2\ \cancel{\text{mol NaOH}}}{1\ \cancel{\text{mol } H_2SO_4}} \times \frac{1000\ \text{ml soln}}{1.420\ \cancel{\text{mol NaOH}}} = 158\ \text{mL}$$