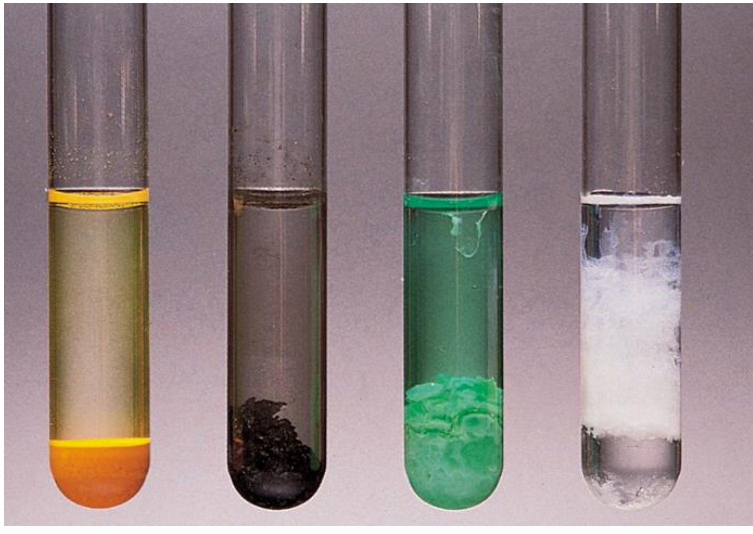
Reactions in Aqueous Solution



Evidence for Chemical Reactions

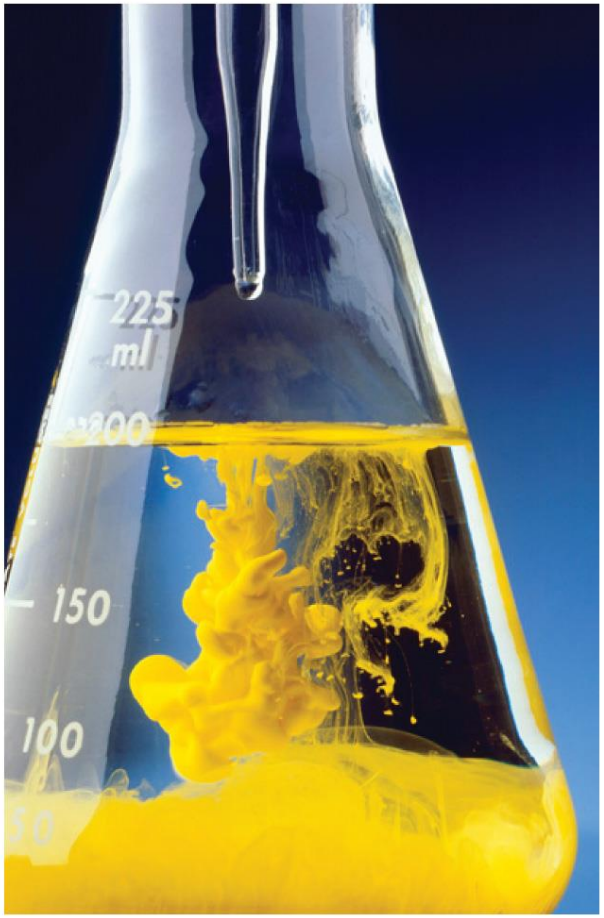
- There are four observations that indicate a chemical reaction is taking place.

1. A gas is produced.

  - Gas may be observed in many ways in a reaction from light fizzing to heavy bubbling.
  - The release of hydrogen gas from the reaction of magnesium metal with acid is shown here.

Evidence for Chemical Reactions, Continued

2. *An insoluble solid is produced in a solution.*

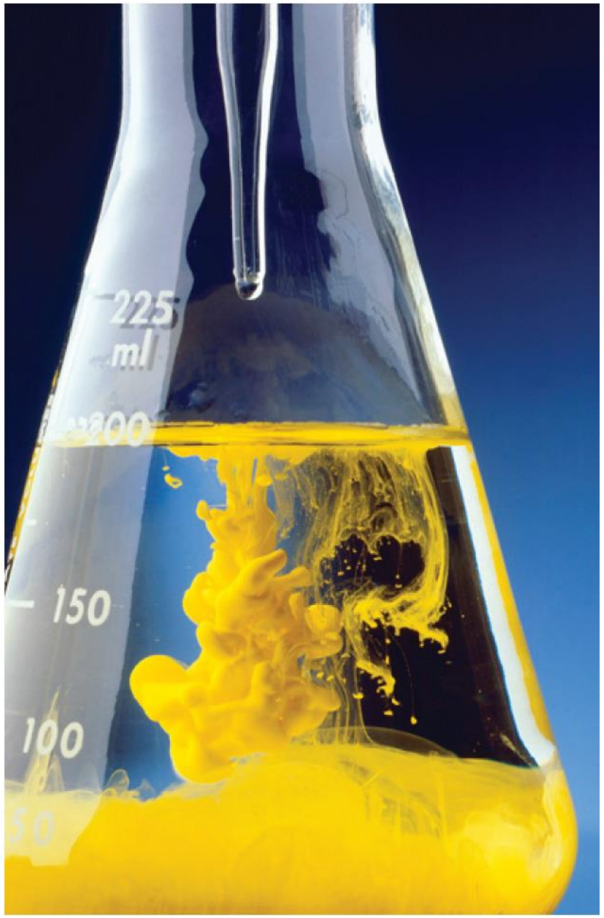


- A substance dissolves in water to give an ***aqueous solution***.
- If we add two aqueous solutions together, we may observe the production of a solid substance.
- The insoluble solid formed is called a ***precipitate***.

Evidence for Chemical Reactions, Continued

3. *A permanent color change is observed.*

- Many chemical reactions involve a permanent color change.
- A change in color indicates that a new substance has been formed.



Evidence for Chemical Reactions, Continued

4. An energy change is observed.

- A reaction that releases heat is an ***exothermic reaction***.
- A reaction that absorbs heat is an ***endothermic reaction***.
- Examples of a heat energy change in a chemical reaction are heat and light being given off.

Chemical Equation Symbols

- Here are several symbols used in chemical equations:

TABLE 7.1 CHEMICAL EQUATION SYMBOLS

SYMBOL	INTERPRETATION OF CHEMICAL EQUATION SYMBOL
$\rightarrow$	produces, yields, gives (separates reactants from products)
$+$	reacts with, added to, plus (separates two or more reactants or products)
$\xrightarrow{\Delta}$	heat is a catalyst for the reaction
$\xrightarrow{Fe}$	iron is a catalyst for the reaction
NR	no reaction
(s)	solid substance or precipitate
(l)	liquid substance
(g)	gaseous substance
(aq)	aqueous solution dung dịch

A Chemical Reaction

- Let's look at a chemical reaction:

$CH_3COOH(aq) + NaHCO_3(s) \rightarrow CH_3COONa(aq) + H_2O(l) + CO_2(g)$

- The equation can be read as follows:
  - Aqueous acetic acid is added to solid sodium carbonate and yields aqueous sodium acetate, liquid water, and carbon dioxide gas.

Types of Chemical Reactions

3 loại advance nên học

- ***Precipitation reactions***: a solid ionic substance forms from the mixture of two solutions of ionic substances.
- ***Acid–base reactions***: reactions that involve the transfer of a proton (H^+) between reactants.
- ***Oxidation–reduction reactions***: reactions that involve the transfer of electrons between reactants.

dung dịch

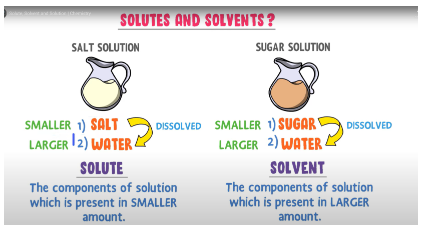
A ***solution*** is a homogenous mixture of 2 or more substances

chất tan

The ***solute*** is(are) the substance(s) present in the smaller amount(s)

dung môi --> ko phải nước lúc nào cũng là dung môi

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

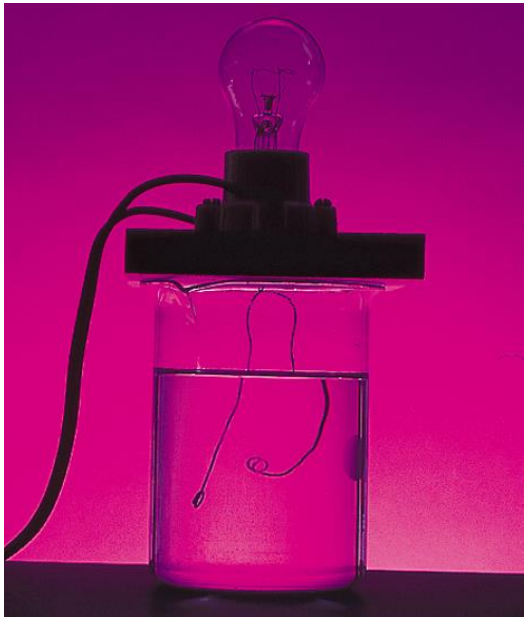


Solution	Solvent	Solute
Soft drink (*l*)	H_2O	Sugar, CO_2
Air (*g*)	N_2	O_2, Ar, CH_4
Soft Solder (*s*)	Pb	Sn

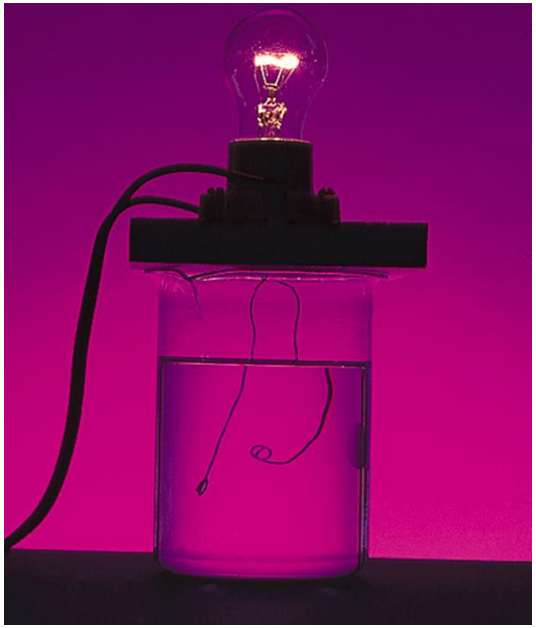
aqueous solutions of $KMnO_4$

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

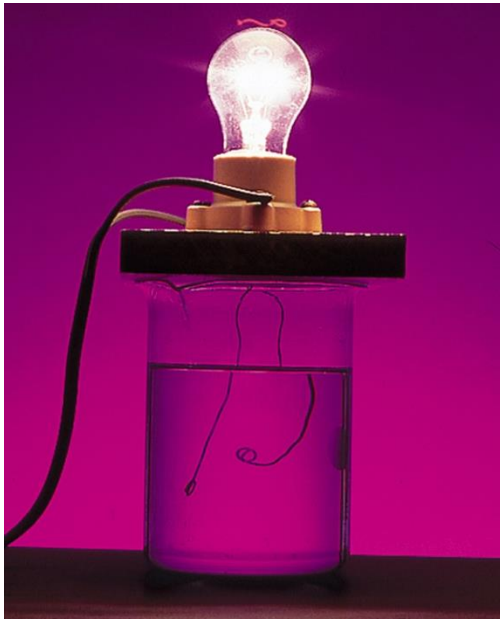
A ***nonelectrolyte*** is a substance that, when dissolved, results in a solution that does not conduct electricity.



nonelectrolyte



weak electrolyte



strong electrolyte

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

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

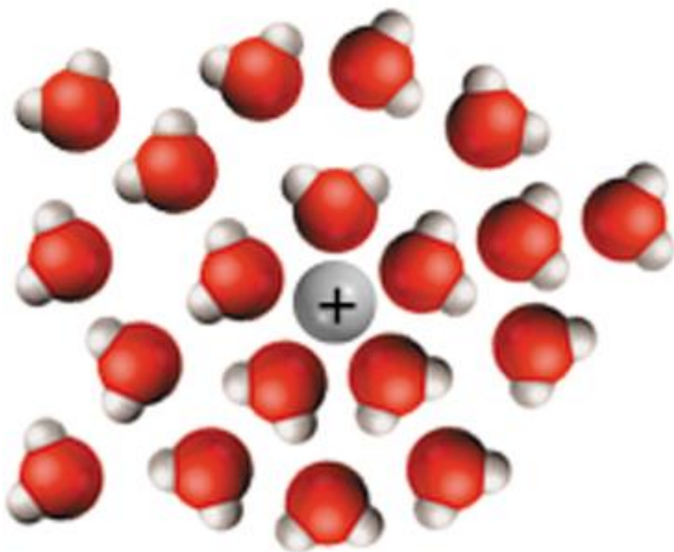
Ionization of acetic acid

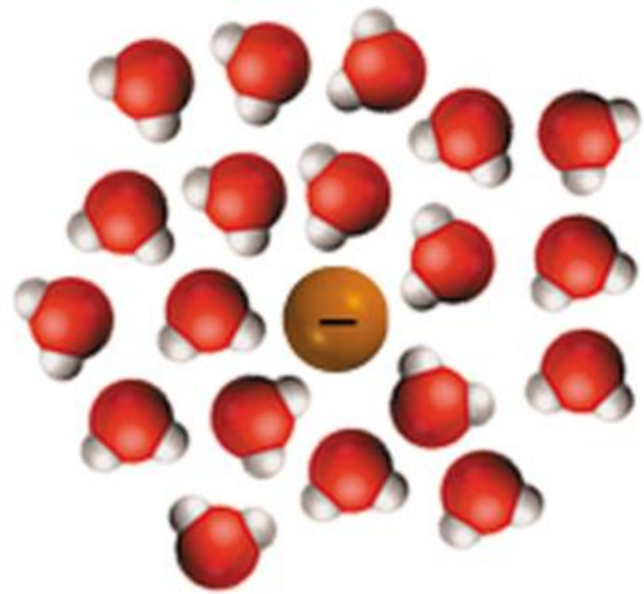
$$CH_3COOH \rightleftharpoons CH_3COO^- \,(aq) + H^+ \,(aq)$$

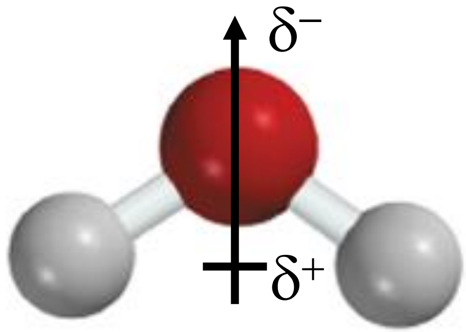
$\rightleftharpoons$ A ***reversible*** reaction. The reaction can occur in both directions.

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

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







H_2O

Nonelectrolyte does not conduct electricity?

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

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

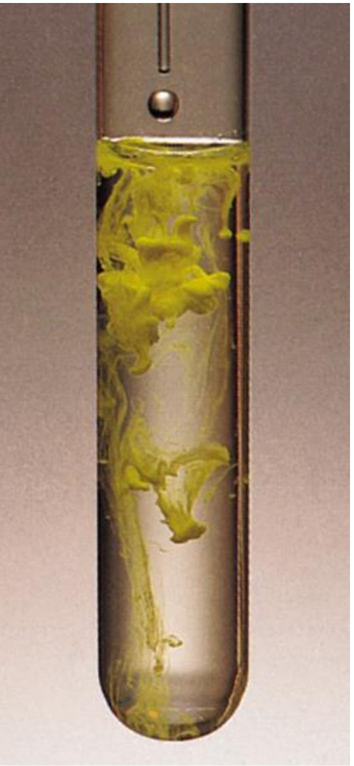
TABLE 4.1 Classification of Solutes in Aqueous Solution

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.

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

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

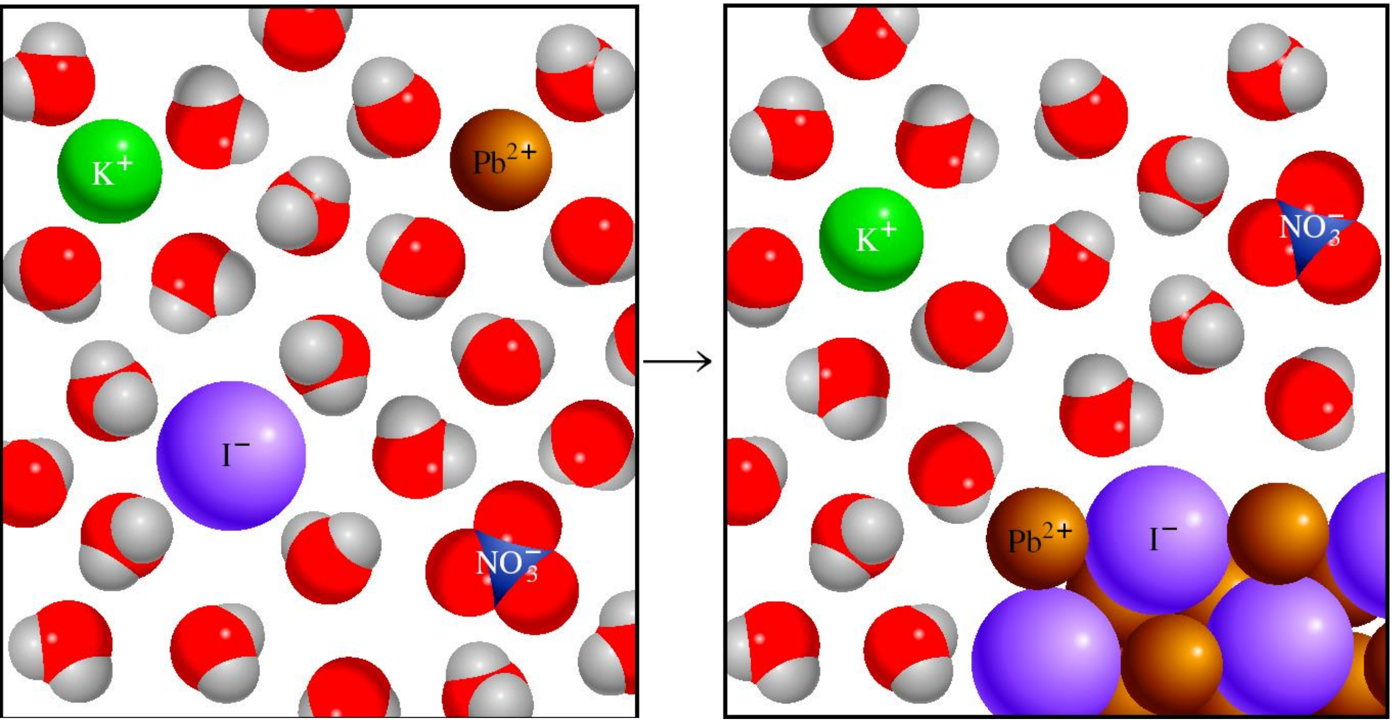
ionic equation

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

net ionic equation

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

Precipitation of Lead Iodide



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

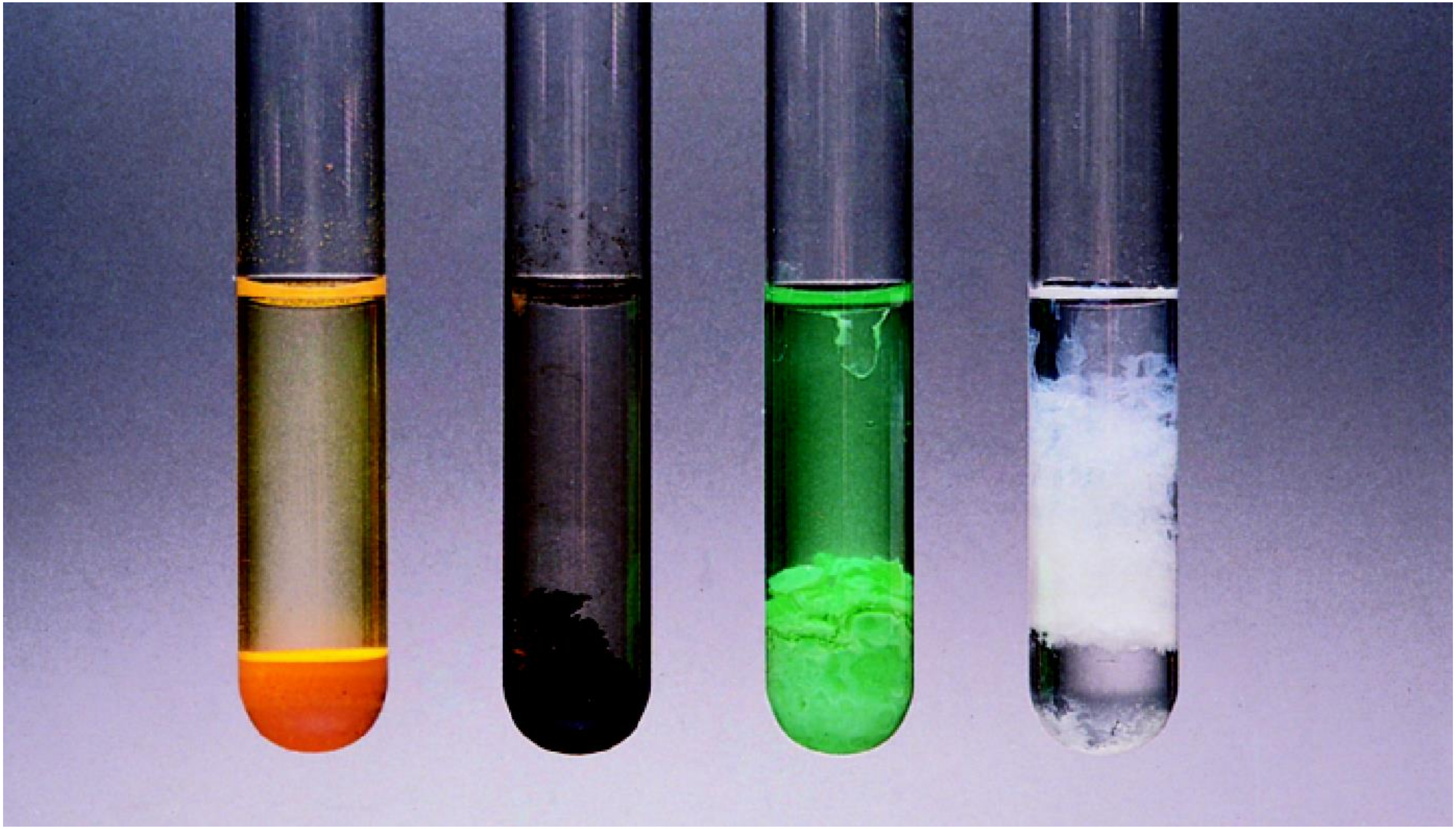
PbI_2

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

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

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.

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

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

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

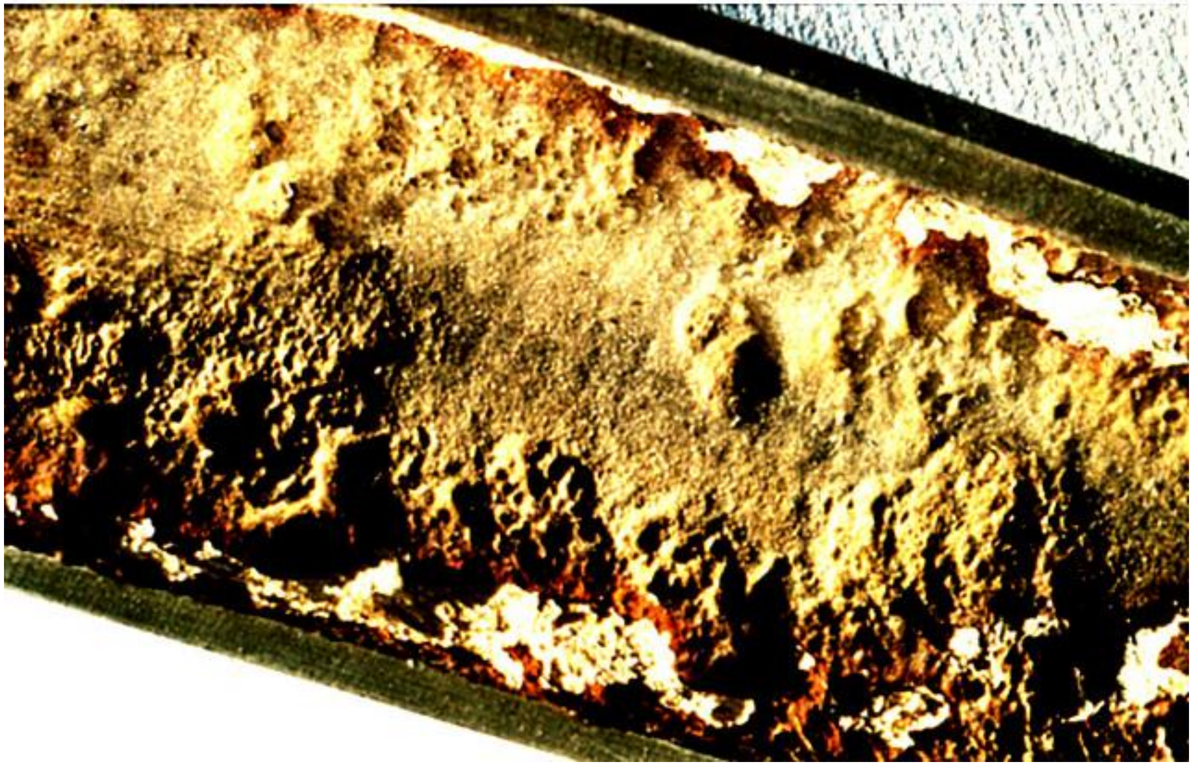
Chemistry In Action:

An Undesirable Precipitation Reaction

$$Ca^{2+}\ (aq) + 2HCO_3^-\ (aq) \longrightarrow CaCO_3\ (s) + CO_2\ (aq) + H_2O\ (l)$$

$$CO_2\ (aq) \longrightarrow CO_2\ (g)$$

Boiler Scale Deposits



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.

Properties of Bases

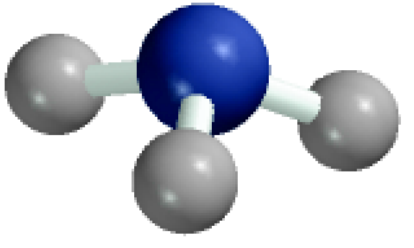
Have a bitter taste.

Feel slippery. Many soaps contain bases.

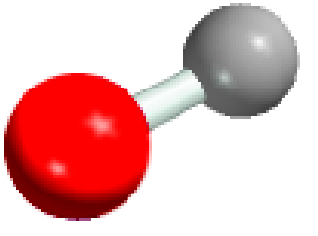
Cause color changes in plant dyes.

Aqueous base solutions conduct electricity.

Examples:

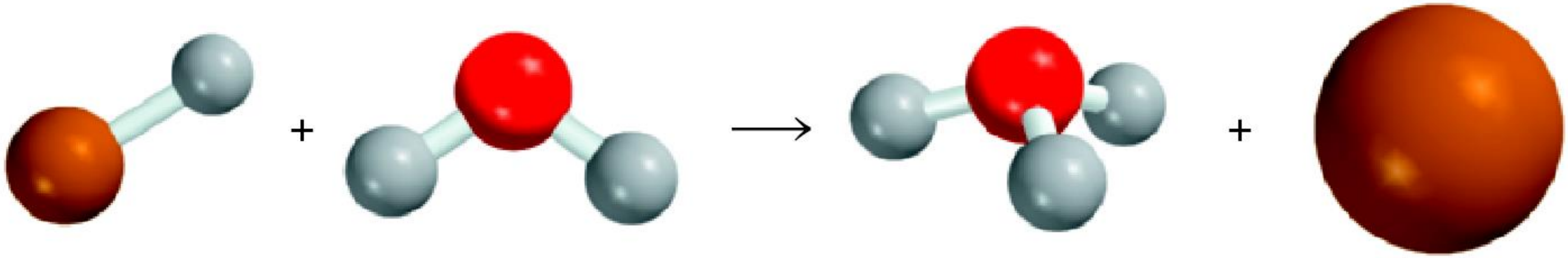


NH_3



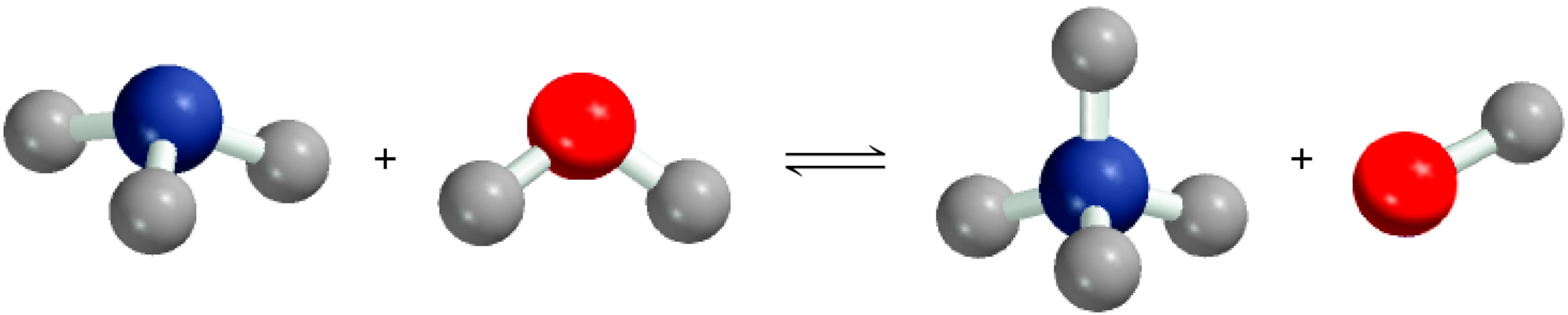
OH^-

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



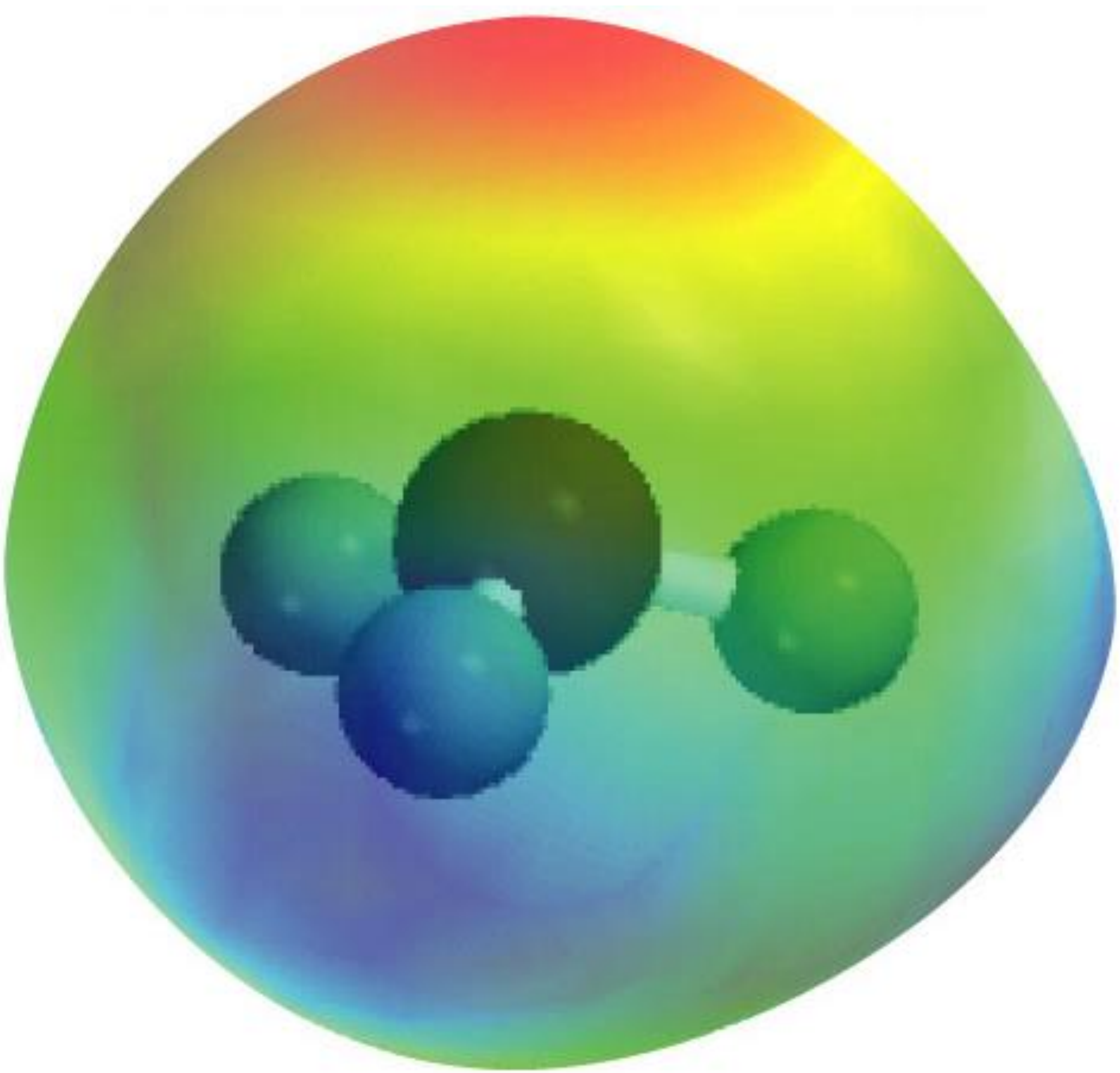
$$HCl + H_2O \longrightarrow H_3O^+ + Cl^-$$

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



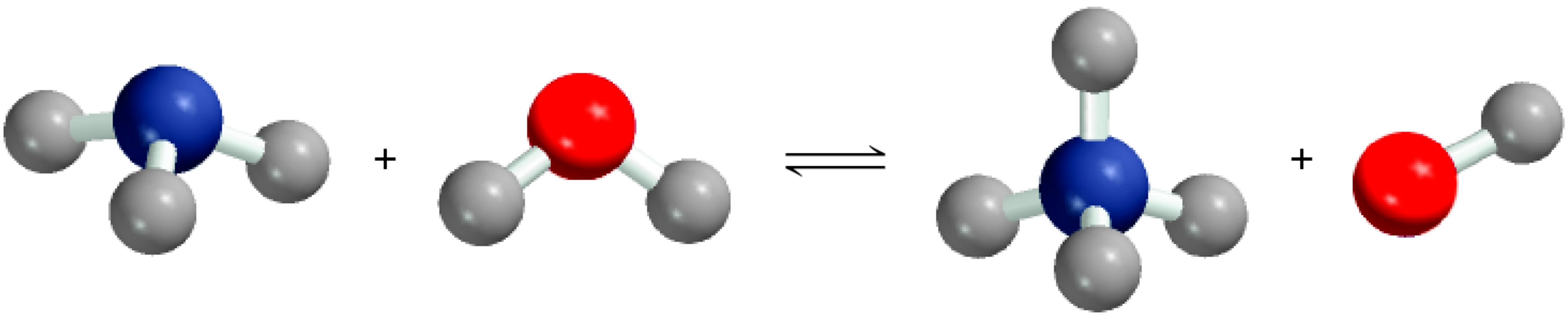
$$NH_3 + H_2O \rightleftharpoons NH_4^+ + OH^-$$

Hydronium ion, hydrated proton, H_3O^+



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!

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

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

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

Neutralization Reaction
(Acid-Base 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

acid + base $\longrightarrow$ salt + water + CO_2

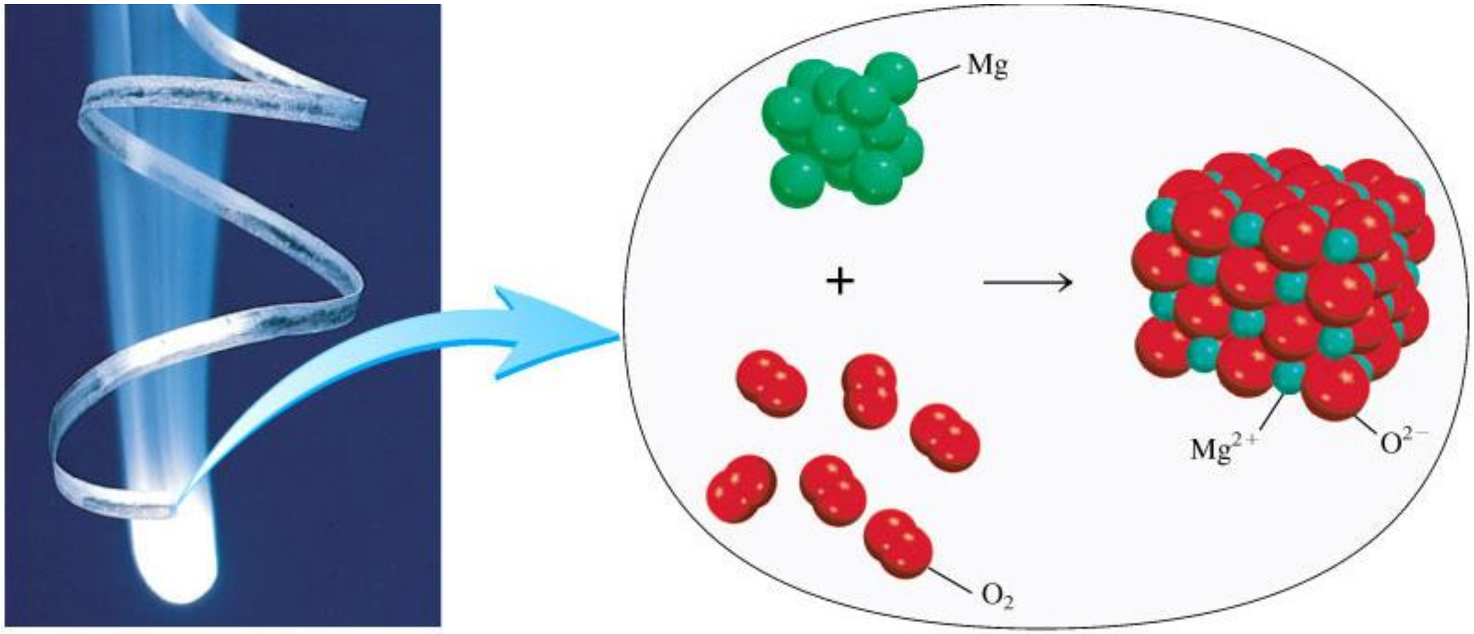
$2HCl\ (aq) + Na_2CO_3\ (aq) \longrightarrow 2NaCl\ (aq) + H_2O + CO_2$

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

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

Oxidation-Reduction Reactions

(electron transfer reactions)

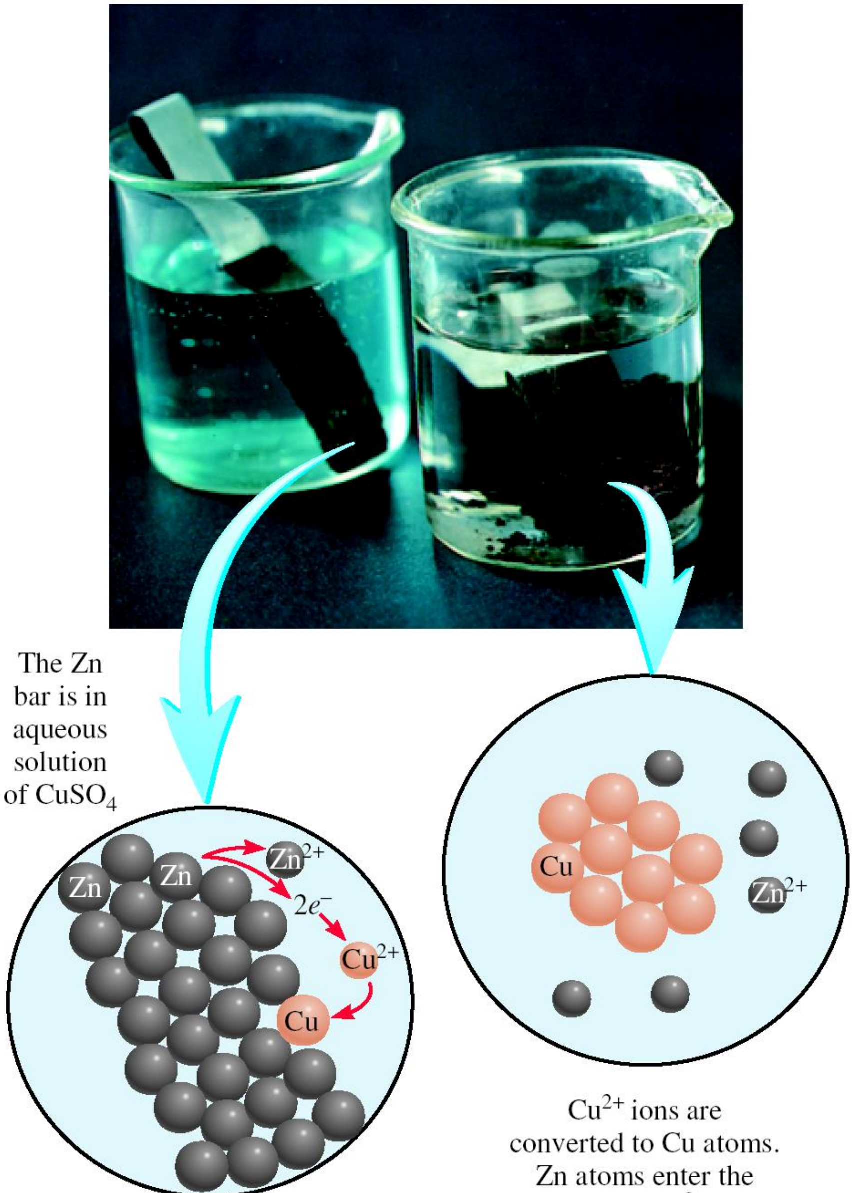


$2Mg \longrightarrow 2Mg^{2+} + 4e^-$ ***Oxidation*** half-reaction (lose e^-)

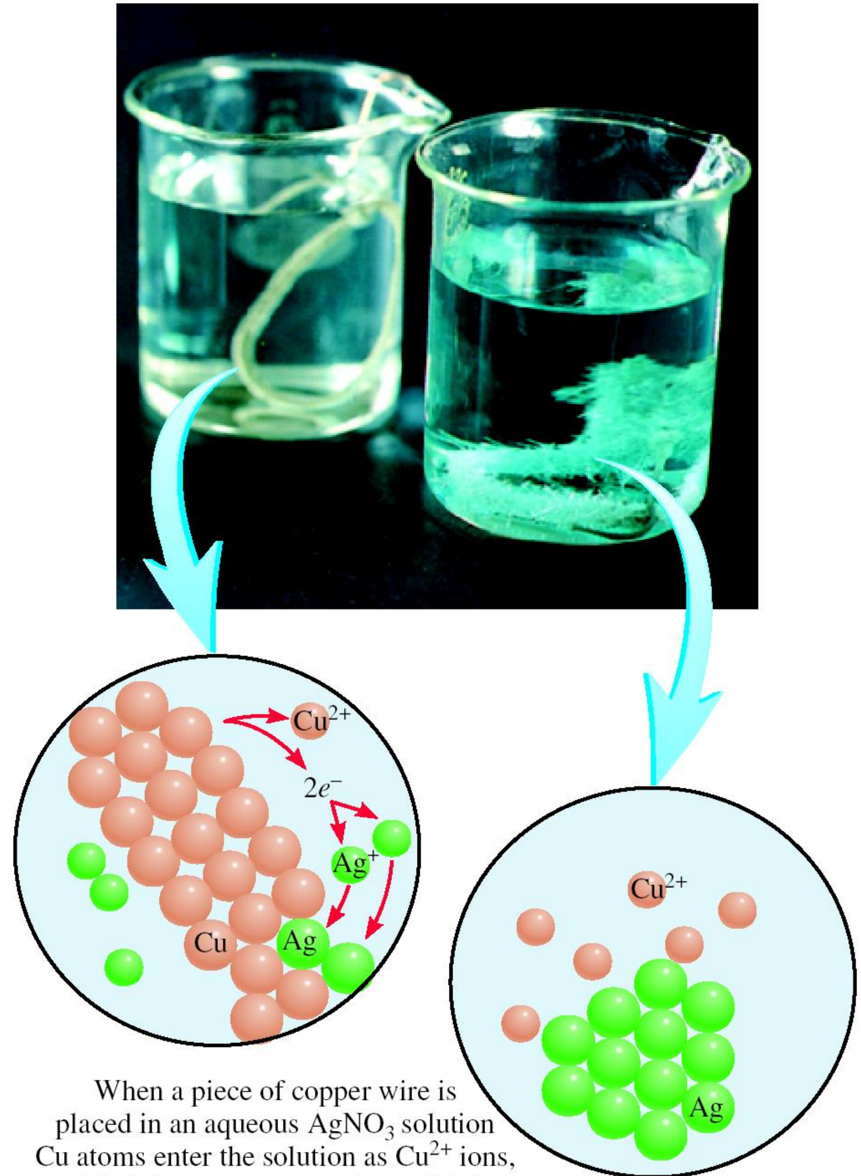
$O_2 + 4e^- \longrightarrow 2O^{2-}$ ***Reduction*** half-reaction (gain e^-)

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

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



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.

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

$Zn \longrightarrow Zn^{2+} + 2e^-$ 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.
What is the oxidizing agent in the reaction?

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

$Cu \longrightarrow Cu^{2+} + 2e^-$

$Ag^+ + 1e^- \longrightarrow Ag$ 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.

4.4

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.

HCO_3^-

What are the oxidation numbers of all the elements in 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	10	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

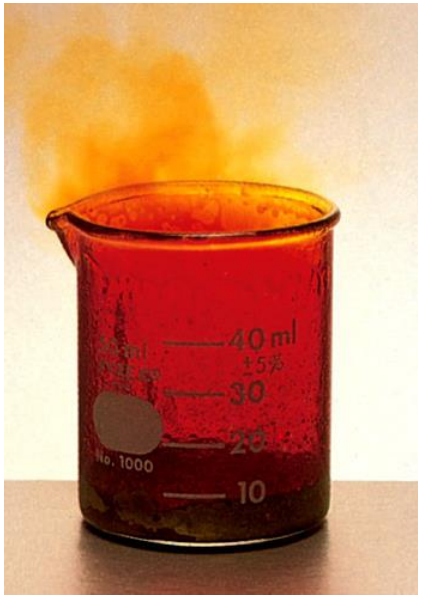
$K_2Cr_2O_7$

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

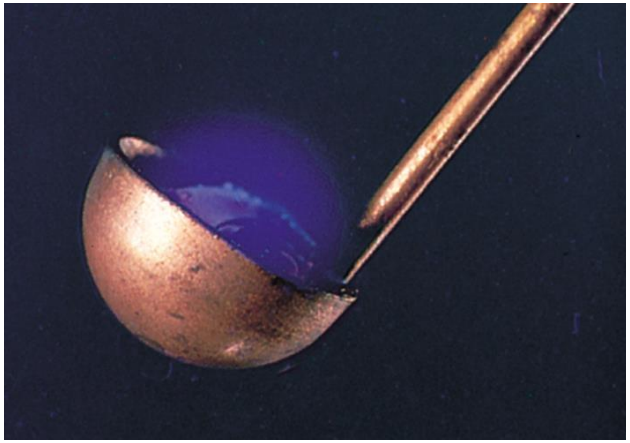
$$C \longrightarrow A + B$$

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

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

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

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

$\overset{+4}{\mathrm{Ti}}\mathrm{Cl}_4 + 2\overset{0}{\mathrm{Mg}} \longrightarrow \overset{0}{\mathrm{Ti}} + 2\overset{+2}{\mathrm{Mg}}\mathrm{Cl}_2$ Metal Displacement

$\overset{0}{\mathrm{Cl}}_2 + 2\mathrm{K}\overset{-1}{\mathrm{Br}} \longrightarrow 2\mathrm{K}\overset{-1}{\mathrm{Cl}} + \overset{0}{\mathrm{Br}}_2$ Halogen Displacement

The Activity Series for Metals

Reducing strength increases ↑

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

<u>Hydrogen Displacement Reaction</u>

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

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

Disproportionation Reaction

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

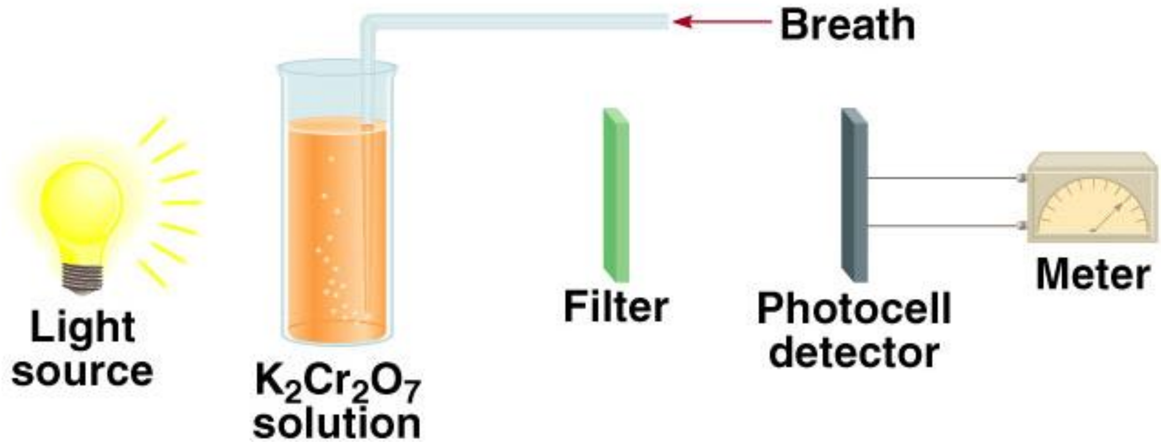
Classify each of the following reactions.

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

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

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



Solution Stoichiometry

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

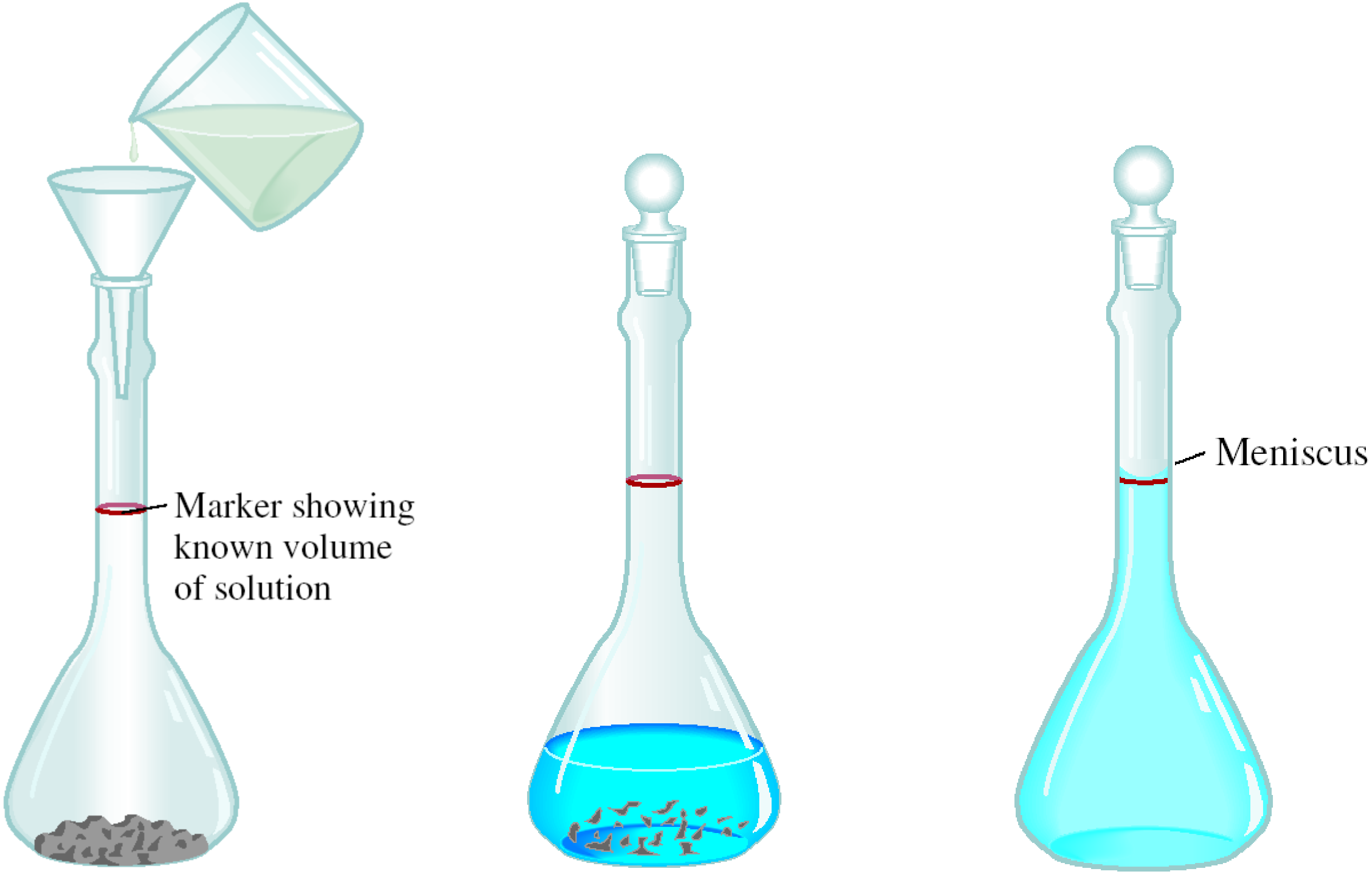
$$\boldsymbol{M} = \textbf{\textit{molarity}} = \frac{\text{moles of solute}}{\text{liters of solution}}$$

What mass of KI is required to make 500. mL of a 2.80 *M* KI solution?

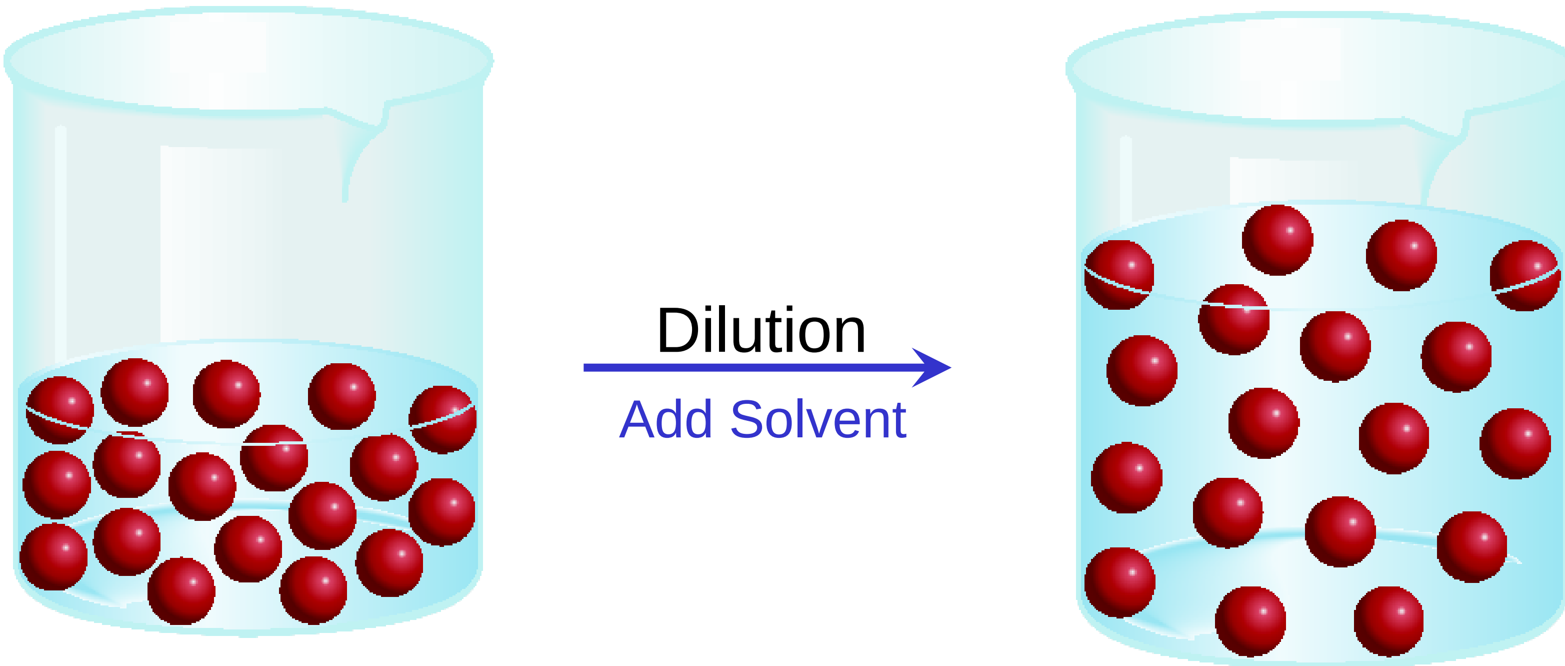
$$\text{volume of KI solution} \xrightarrow{M\ \text{KI}} \text{moles KI} \xrightarrow{\mathcal{M}\ \text{KI}} \text{grams KI}$$

$$500.\ \cancel{\text{mL}} \times \frac{1\ \cancel{\text{L}}}{1000\ \cancel{\text{mL}}} \times \frac{2.80\ \cancel{\text{mol}}\ \text{KI}}{1\ \cancel{\text{L}}\ \text{soln}} \times \frac{166\ \text{g KI}}{1\ \cancel{\text{mol}}\ \text{KI}} = 232\ \text{g KI}$$

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?

$$M_i V_i = M_f V_f$$

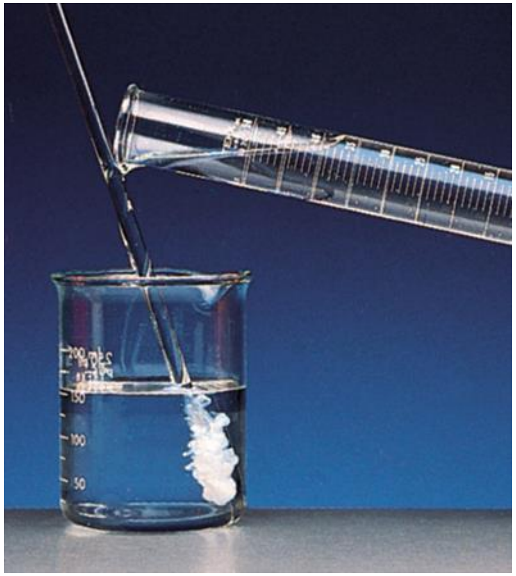
$M_i = 4.00\ M$ $M_f = 0.200\ M$ $V_f = 0.0600$ L $V_i = ?$ L

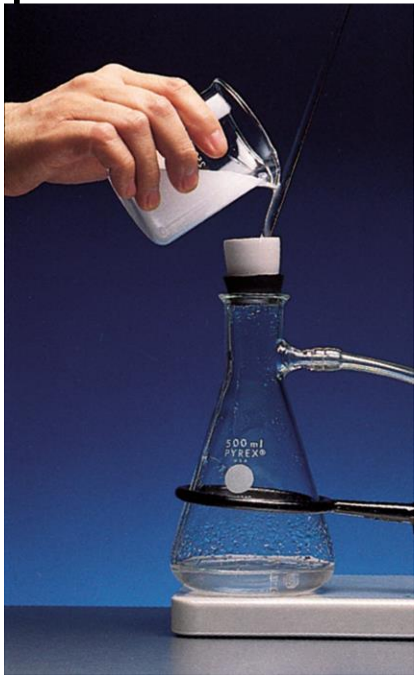
$$V_i = \frac{M_f V_f}{M_i} = \frac{0.200\ M \times 0.0600\ \text{L}}{4.00\ M} = 0.00300\ \text{L} = 3.00\ \text{mL}$$

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

Gravimetric Analysis

1. Dissolve unknown substance in water
2. React unknown with known substance to form a precipitate
3. Filter and dry precipitate
4. Weigh precipitate
5. Use chemical formula and mass of precipitate to determine amount of unknown ion



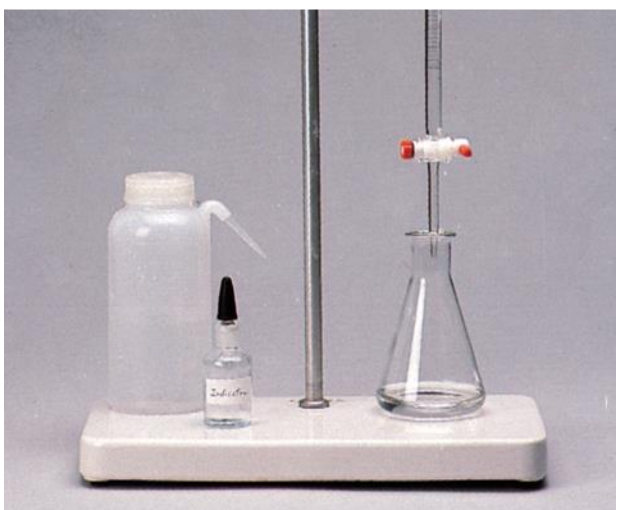


Titrations

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

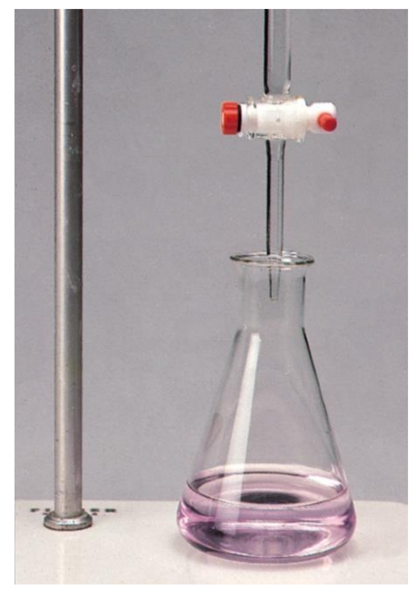
Equivalence point – the point at which the reaction is complete

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



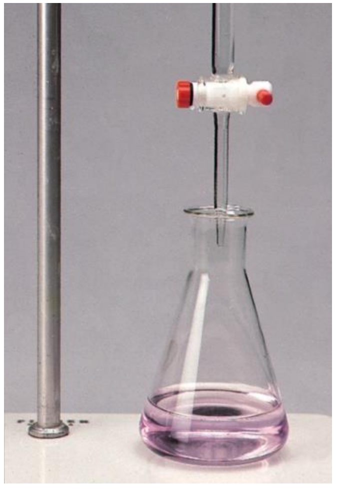
Slowly add base to unknown acid UNTIL

the indicator changes color



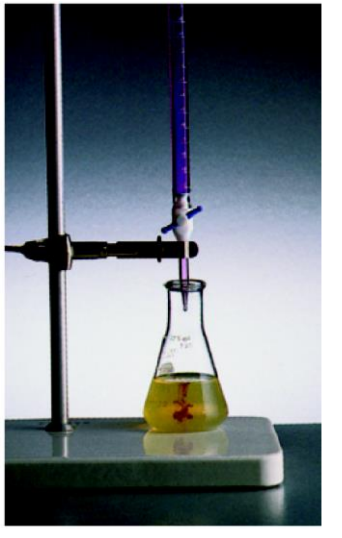
Titrations can be used in the analysis of

Acid-base reactions



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

Redox reactions



$$5Fe^{2+} + MnO_4^- + 8H^+ \longrightarrow Mn^{2+} + 5Fe^{3+} + 4H_2O$$

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!

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

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

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

16.42 mL of 0.1327 *M* $KMnO_4$ solution is needed to oxidize 25.00 mL of an acidic $FeSO_4$ solution. What is the molarity of the iron solution?

WRITE THE CHEMICAL EQUATION!

$$5Fe^{2+} + MnO_4^- + 8H^+ \longrightarrow Mn^{2+} + 5Fe^{3+} + 4H_2O$$

$$\text{volume red} \xrightarrow[\text{red}]{M} \text{moles red} \xrightarrow[\text{coef.}]{\text{rxn}} \text{moles oxid} \xrightarrow[\text{oxid}]{V} M \text{ oxid}$$

16.42 mL = 0.01642 L

25.00 mL = 0.02500 L

$$0.01642\ \cancel{L} \times \frac{0.1327\ \cancel{\text{mol KMnO}_4}}{1\ \cancel{L}} \times \frac{5\ \text{mol Fe}^{2+}}{1\ \cancel{\text{mol KMnO}_4}} \times \frac{1}{0.02500\ \text{L Fe}^{2+}} = 0.4358\ M$$

Chemistry in Action: Metals from the Sea

$$CaCO_3\ (s) \longrightarrow CaO\ (s) + CO_2\ (g)$$

$$CaO\ (s) + H_2O\ (l) \longrightarrow Ca^{2+}\ (aq) + 2OH^-\ (aq)$$

$$Mg^{2+}\ (aq) + 2OH^-\ (aq) \longrightarrow Mg(OH)_2\ (s)$$

$$Mg(OH)_2\ (s) + 2HCl\ (aq) \longrightarrow MgCl_2\ (aq) + 2H_2O\ (l)$$

$$Mg^{2+} + 2e^- \longrightarrow Mg$$

$$2Cl^- \longrightarrow Cl_2 + 2e^-$$

$$MgCl_2\ (aq) \longrightarrow Mg\ (s) + Cl_2\ (g)$$

Magnesium Hydroxide