Professor K

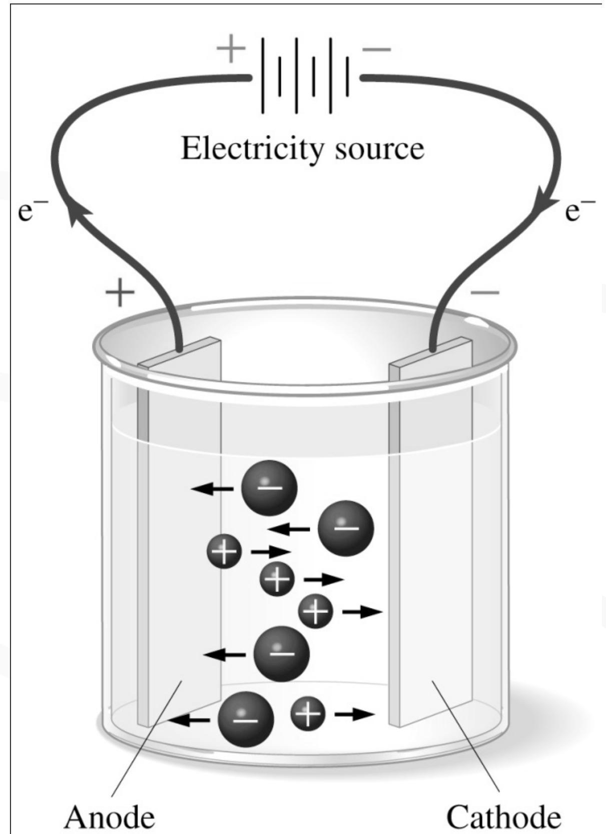
Reactions

Chemical reactions

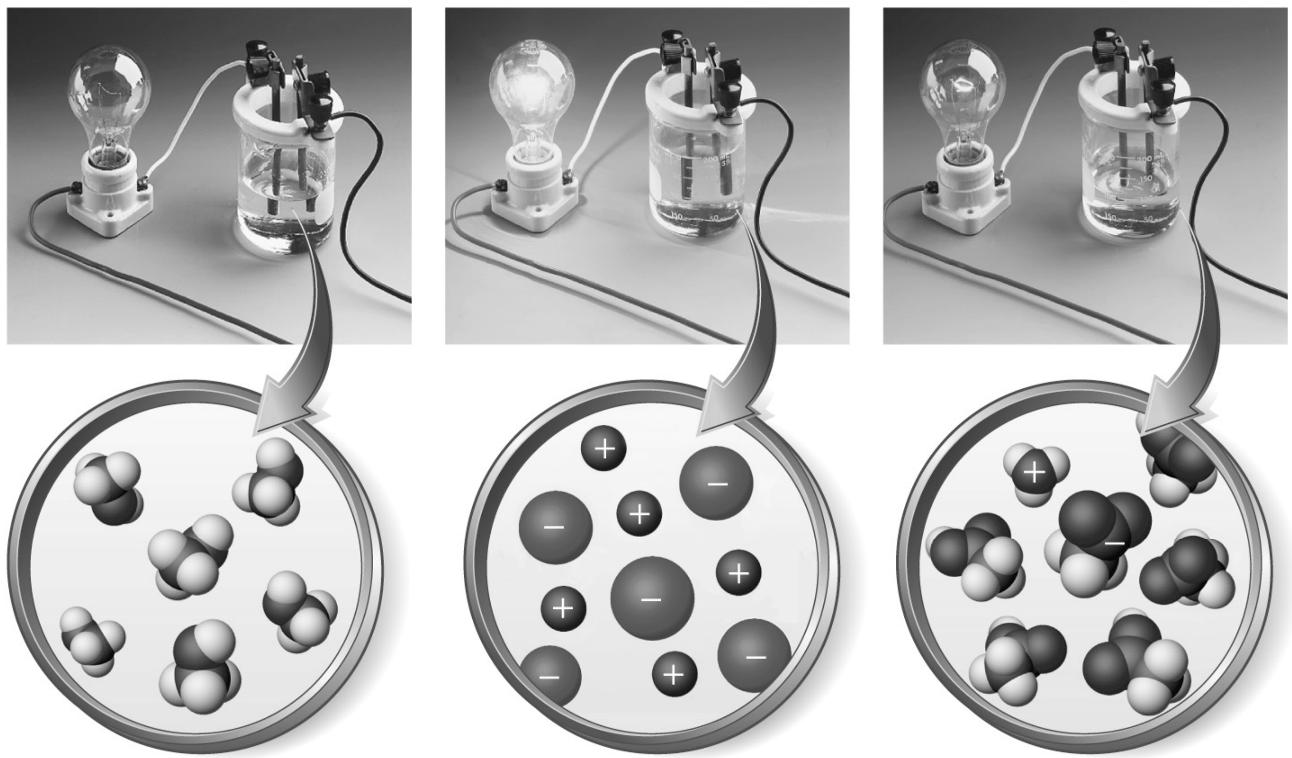
- How do the atoms and molecules come together so that their bonds can be broken and formed (the definition of a chemical reaction)?
- Solids are commonly made into solutions.

Electricity

- The flow of charged particles.
- What enables this flow through a liquid?
- The presence of charged particles, or IONS (CATION positive, ANION negative). being drawn to the cathode (negative) and anode (positive).
- In a strong ELECTROLYTE, the solute DISSOCIATES completely and is present almost entirely as ions.
- In a NONELECTROLYTE, the solute exists almost entirely as NON-DISSOCIATED molecules.
- A weak electrolyte exists as both ions and molecules in solution. There exists an EQUILIBRIUM between the molecules and ions (next slide).



Electrolytes



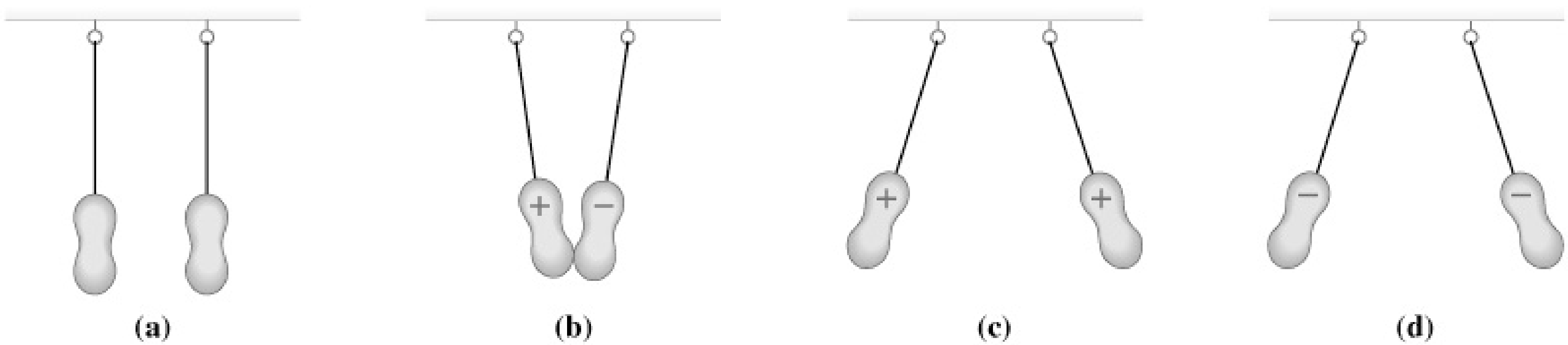
(a)
1 M CH_3OH
Nonelectrolyte
Solute consists
of molecules;
no ions

(b)
1 M NaCl(aq)
Strong electrolyte
Solute consists of ions:
Na^+ Cl^-

(c)
1 M CH_3COOH(aq)
Weak electrolyte Solute consists
mostly of molecules; some ions:
CH_3COO^- H_3O^+

Electrostatic forces

- Unlike charges (+ and –) attract one another
- Like charges (+ and +, or – and –) repel one another
- Different from "like dissolves like" when discussing solutions



Ion concentration

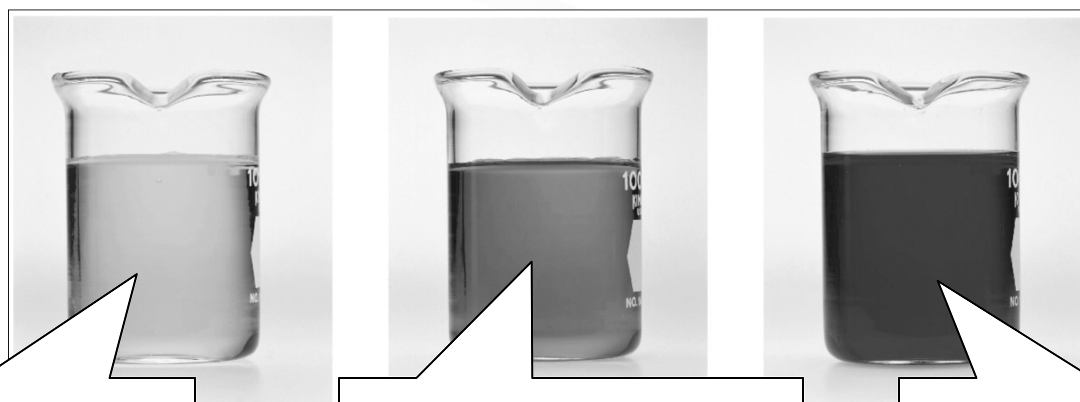
- A strong electrolyte like 1 mole of NaCl would generate 1 mole of Na^+ ions and 1 mole of Cl^- ions in solution.
- 1 mole of Na_2SO_4 would generate 2 moles of sodium ions and 1 mole of sulfate ions

Example

- Calculate the molarity of each ion in an aqueous solution that is 0.00384 M Na_2SO_4 and 0.00202 M NaCl.
- In addition, calculate the total ion concentration of the solution.

Acids and bases

- Remember your definitions
- Strong acids and bases are strong electrolytes
- We measure acid and base strength using a pH meter or an indicator (see below)
- For a POLYPROTIC acid like H_2SO_4 the first ionization is generally stronger than the second (more later)
- Acid plus base makes salt plus water- NEUTRALIZATION



Common strong acids and strong bases

Not HF!

A pragmatic method of determining whether an acid is weak … just learn the strong acids!

Table 4.1 Common Strong Acids and Strong Bases

Acids		Bases	
Binary Hydrogen Compounds	Oxoacids	Group 1A hydroxides	Group 2A hydroxides
HCl	HNO_3	LiOH	$Mg(OH)_2$
HBr	H_2SO_4[a]	NaOH	$Ca(OH)_2$
HI	$HClO_4$	KOH	$Sr(OH)_2$
		RbOH	$Ba(OH)_2$
		CsOH	

[a] H_2SO_4 is a strong acid in its first ionization step but weak in its second ionization step.

Equations

- A NET IONIC EQUATION shows only the particles undergoing change in the reaction
- Ex- $HCl(aq) + NaOH(aq) \rightarrow NaCl(aq) + H_2O(l)$
  FULL EQUATION (for the neutralization)
- $H^+(aq) + Cl^-(aq) + Na^+(aq) + OH^-(aq) \rightarrow$
  $Na^+(aq) + Cl^-(aq) + H_2O(l)$
  IONIC EQUATION
- $H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$
  NET IONIC EQUATION
- Ions left out of the net ionic equation are SPECTATOR IONS

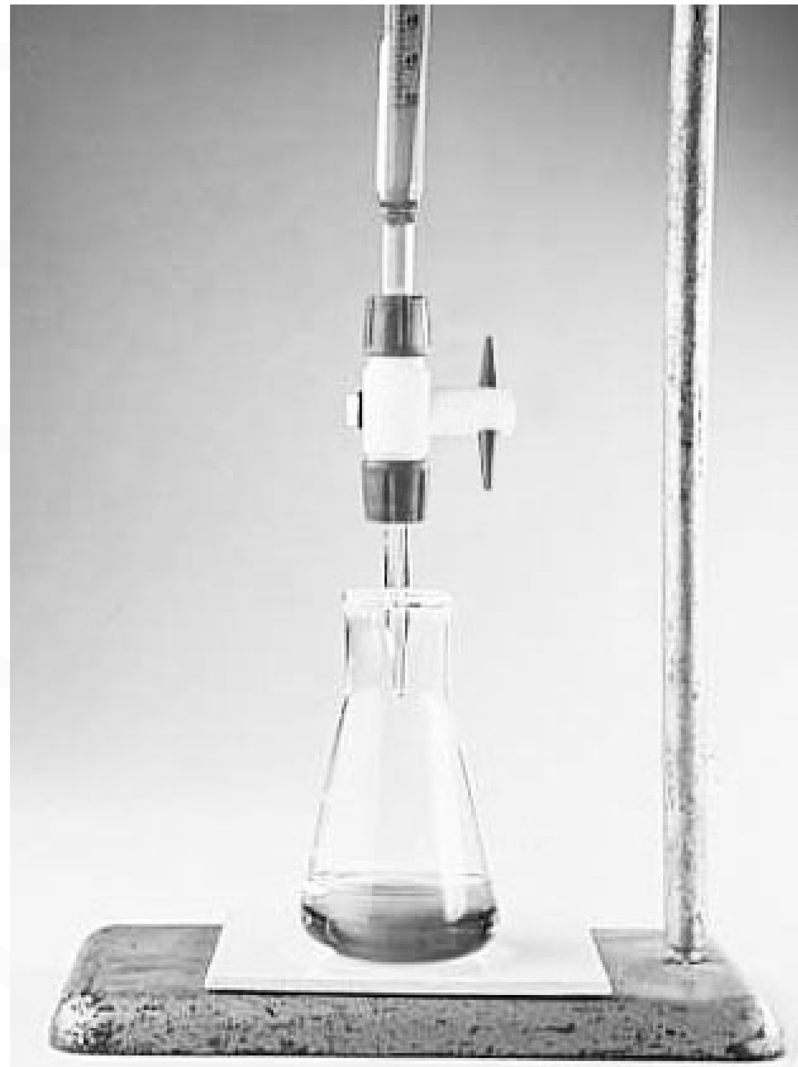
Example

- Barium nitrate, used to produce a green color in fireworks, can be made by the reaction of nitric acid with barium hydroxide. Write (a) a complete-formula equation, (b) an ionic equation, and (c) a net ionic equation for this neutralization reaction.

Titration

(you will do this extensively in lab)

- Experimental technique which allows you to determine concentration of an ANALYTE by employing reaction STOICHIOMETRY
- The TITRANT is added to a flask of sample using a BURET until the EQUIVALENCE POINT or END POINT is reached
- Can be an acid/base titration, a precipitation titration, or a redox titration



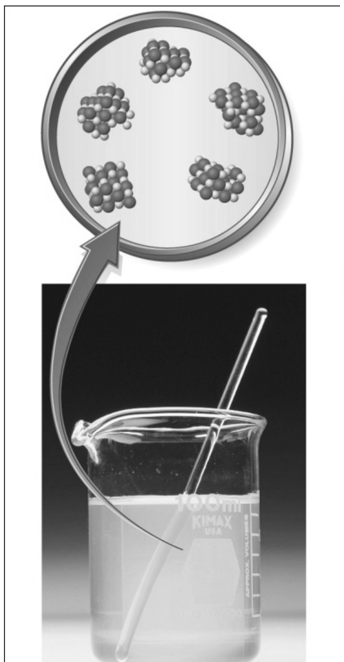
Examples

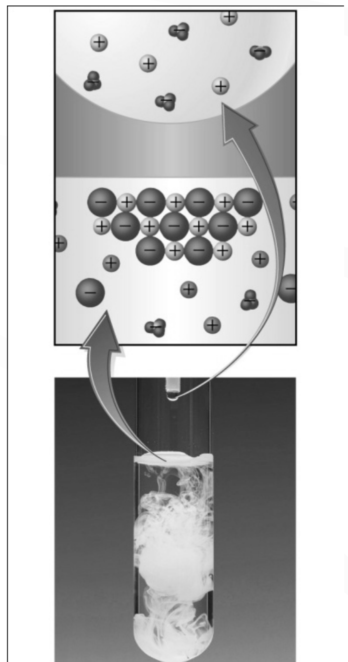
- What volume (mL) of 0.2010 M NaOH is required to neutralize 20.00 mL of 0.1030 M HCl in an acid–base titration?

- A 10.00-mL sample of an aqueous solution of calcium hydroxide is neutralized by 23.30 mL of 0.02000 M HNO_3(*aq*). What is the molarity of the calcium hydroxide solution?

Precipitation reactions

- When some cations and anions are combined a product which is insoluble in water (<0.01M) sometimes results. The insoluble product is a PRECIPITATE.
- The real world often believes in moderation, so very often, compounds are neither completely SOLUBLE nor completely INSOLUBLE- they may be SPARINGLY SOLUBLE, existing in a DYNAMIC EQUILIBRIUM





Solubility rules

Table 4.3 General Guidelines for the Water Solubilities of Common Ionic Compounds
Almost all nitrates, acetates, perchlorates, group 1A metal salts, and ammonium salts are *SOLUBLE*.
Most chlorides, bromides, and iodides are *SOLUBLE*. Exceptions: those of Pb^{2+}, Ag^{+}, and Hg_2^{2+}.
Most sulfates are *SOLUBLE*. Exceptions: those of Sr^{2+}, Ba^{2+}, Pb^{2+}, and Hg_2^{2+} ($CaSO_4$ is slightly soluble).
Most carbonates, hydroxides, phosphates, and sulfides are *INSOLUBLE*. Exceptions: ammonium and group 1A metal salts of any of those anions are soluble; hydroxides and sulfides of Ca^{2+}, Sr^{2+}, and Ba^{2+} are slightly to moderately soluble.

Example

Predict whether a precipitation reaction will occur in each of the following cases. If so, write a net ionic equation for the reaction.

(a) $Na_2SO_4(aq) + MgCl_2(aq) \rightarrow ?$

(b) $(NH_4)_2S(aq) + Cu(NO_3)_2(aq) \rightarrow ?$

(c) $K_2CO_3(aq) + ZnCl_2(aq) \rightarrow ?$

Example

A Conceptual Example

The figure shows that the dropwise addition of $NH_3(aq)$ to $FeCl_3(aq)$ produces a precipitate. What is the precipitate?

Precipitation in action

Table 4.4 Some Precipitation Reactions of Practical Importance

Reaction in Aqueous Solution	Application
$Al^{3+}(aq) + 3\,OH^-(aq) \longrightarrow Al(OH)_3(s)$	Water purification. (The gelatinous precipitate carries down suspended matter.)
$Al^{3+}(aq) + PO_4{}^{3-}(aq) \longrightarrow AlPO_4(s)$	Removal of phosphates from wastewater in sewage treatment.
$Mg^{2+}(aq) + 2\,OH^-(aq) \longrightarrow Mg(OH)_2(s)$	Precipitation of magnesium ion from seawater. (First step in the Dow process for extracting magnesium from seawater.)
$Ag^+(aq) + Br^-(aq) \longrightarrow AgBr(s)$	Preparation of AgBr for use in photographic film.
$Zn^{2+}(aq) + SO_4{}^{2-}(aq) + Ba^{2+}(aq) + S^{2-}(aq) \longrightarrow ZnS(s) + BaSO_4(s)$	Production of *lithopone*, a mixture used as a white pigment in both water paints and oil paints.
$H_3PO_4(aq) + Ca(OH)_2(aq) \longrightarrow CaHPO_4 \cdot 2\,H_2O(s)$	Preparation of calcium hydrogen phosphate dihydrate, used as a polishing agent in toothpastes.

Oxidation states

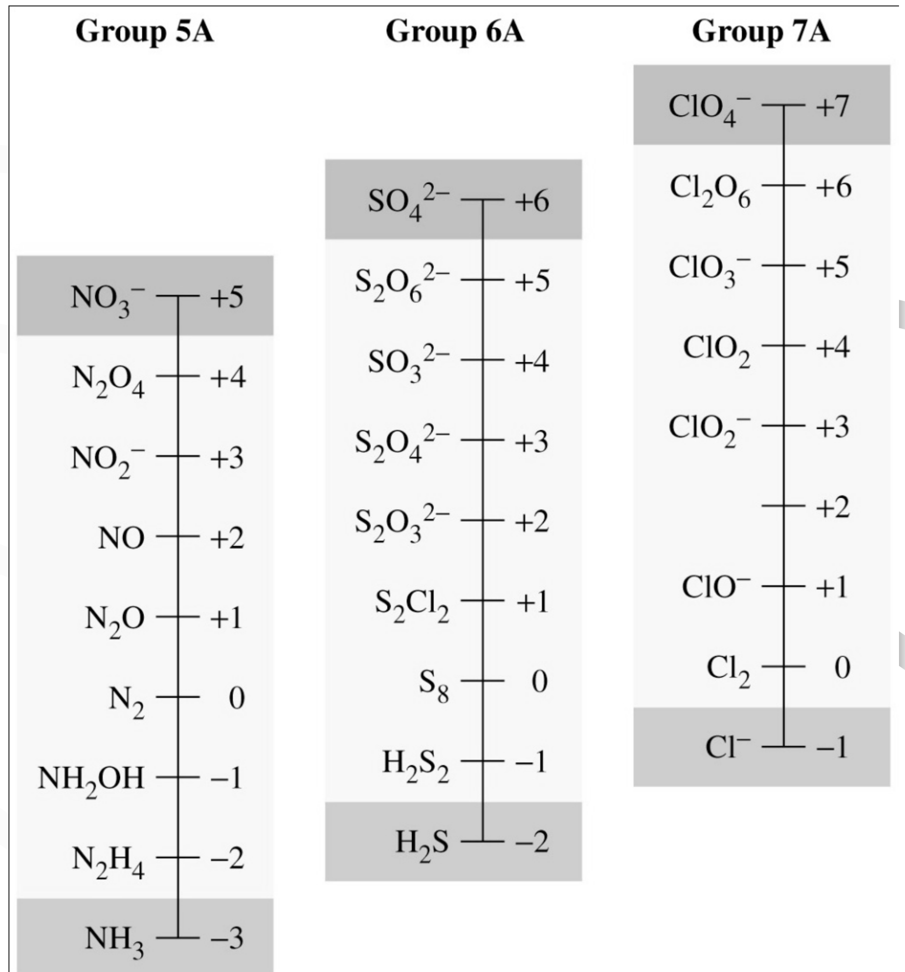
- An OXIDATION NUMBER represents the actual charge on a monatomic ion or a *hypothetical* charge assigned to an atom in a molecule or polyatomic ion

Rules for determining oxidation states

- For a neutral species, the sum of all the oxidation numbers is zero
- For a reaction, the sum of all the oxidation numbers of reactants must equal the sum of all the oxidation numbers of the products (conservation of charge)
- Group 1A metals have a charge of +1 in their compounds
- Group 2A metals have a charge of +2 in their compounds
- In binary compounds, the ox. no. of Group 7A elements is -1
- In binary compounds, the ox. no. of Group 6A elements is -2
- In binary compounds, the ox. no. of Group 5A elements is -3
- In its compounds, the ox. no. of F is -1
- In its compounds, the ox. no. of H is +1
- In its compounds, the ox. no. of O is -2

Rules for determining oxidation states (con't)

- WHY??? There exists a HYPERSTABILITY of an ion when it has as many electrons as its nearest noble gas element
- For non-binary compounds, start with what you know and go from there. For example, in NO_3^-, since each oxygen is -2, the nitrogen must be +5



Example

- What are the oxidation numbers assigned to the atoms of each element in:
  - $KClO_4$
  - $Cr_2O_7^{2-}$
  - CaH_2
  - Na_2O_2

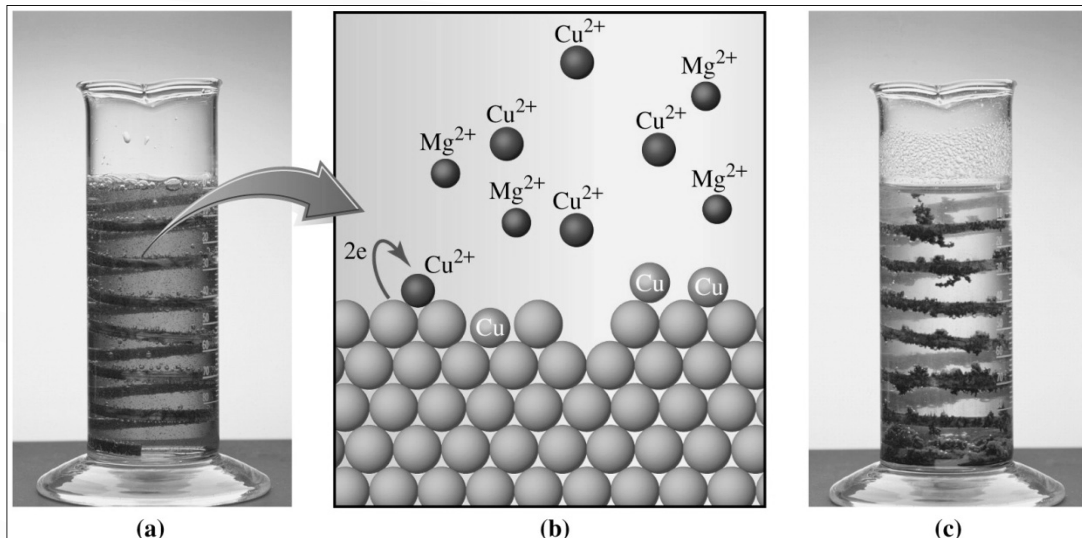
Redox reactions

- Oxidation states change
- An element whose oxidation number increases (LOSES e^-) (or becomes less negative) upon going from reactant to product is being OXIDIZED
- An element whose oxidation number decreases (GAINS e^-) (or becomes more negative) upon going from reactant to product is being REDUCED
  - The compound DOING the reducing is the REDUCING AGENT.
    - Note that in DOING the reducing, the REDUCING AGENT gets OXIDIZED.
  - The compound DOING the oxidizing is the OXIDIZING AGENT.
    - Note that in DOING the oxidizing, the OXIDIZING AGENT gets REDUCED.

Redox reactions (cont'd)

$$\overset{0}{Mg(s)} + \overset{+2}{Cu^{2+}(aq)} \longrightarrow \overset{+2}{Mg^{2+}(aq)} + \overset{0}{Cu(s)}$$

- The compound DOING the reducing is the REDUCING AGENT.
  - The REDUCING AGENT gets OXIDIZED (loses e^-).
- The compound DOING the oxidizing is the OXIDIZING AGENT.
  - The OXIDIZING AGENT gets REDUCED (gains e^-) .



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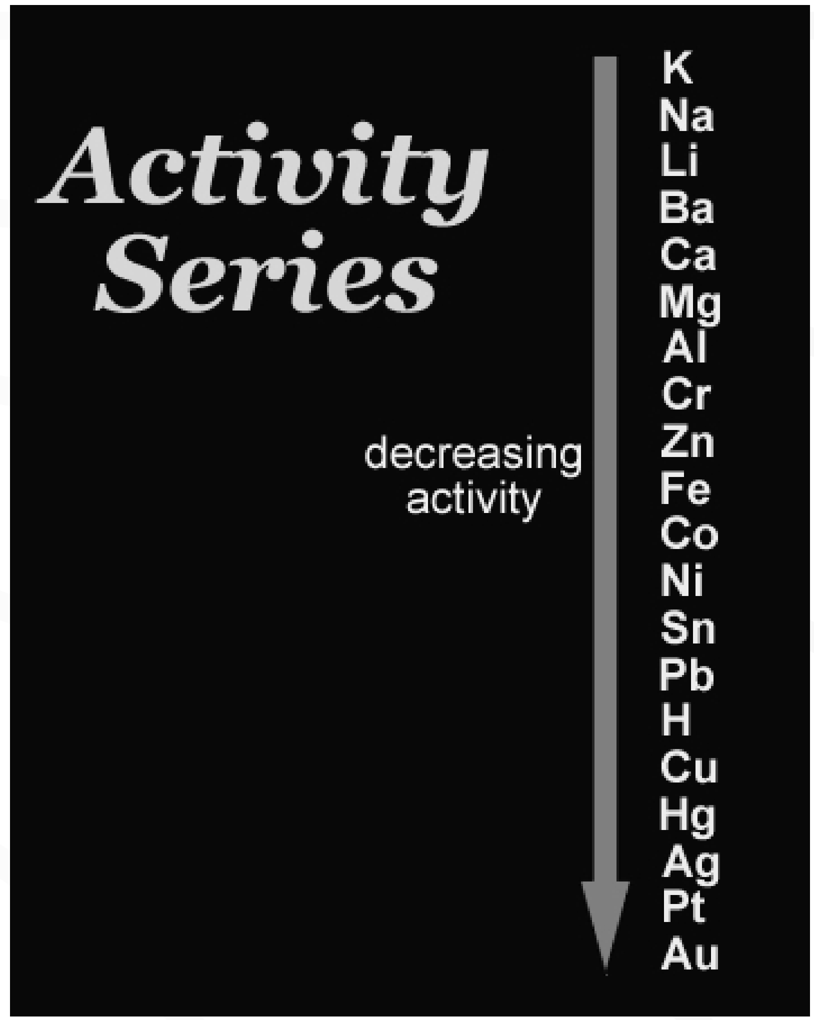
Activity series

- We will discuss this in more depth when we talk about electrochemistry, but for now, a metal will displace from solution any ion that lies below it on the activity series (strength as a reducing agent)



Redox reactions (cont'd)

- In a redox reaction, BOTH the ATOMS and CHARGES must be balanced
- A reactant that undergoes BOTH oxidation and reduction in the same reaction is involved in a DISPROPORTIONATION

$$2H_2O_2 \rightarrow 2H_2O + O_2$$

More practical examples

- Burning = combustion = rusting = “oxidation”

- What is happening when octane burns?
- What is happening when a nail rusts?