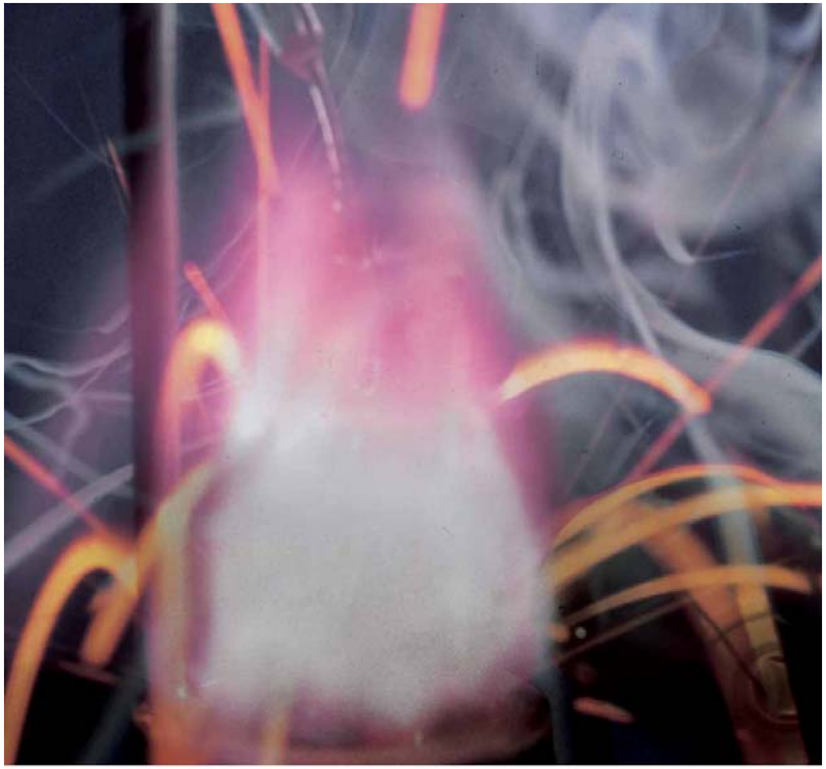
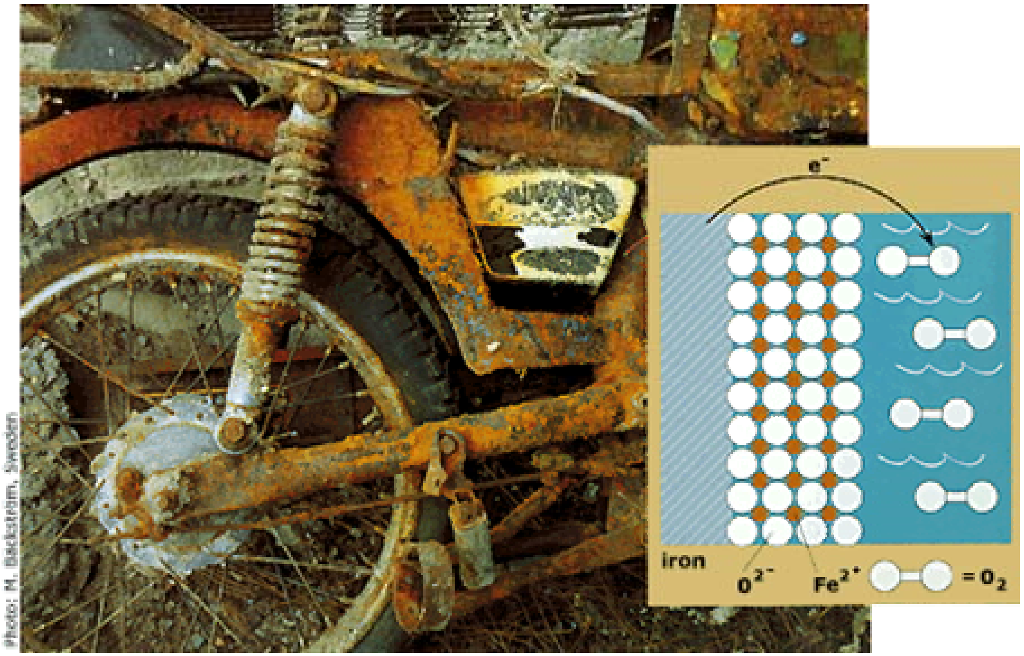
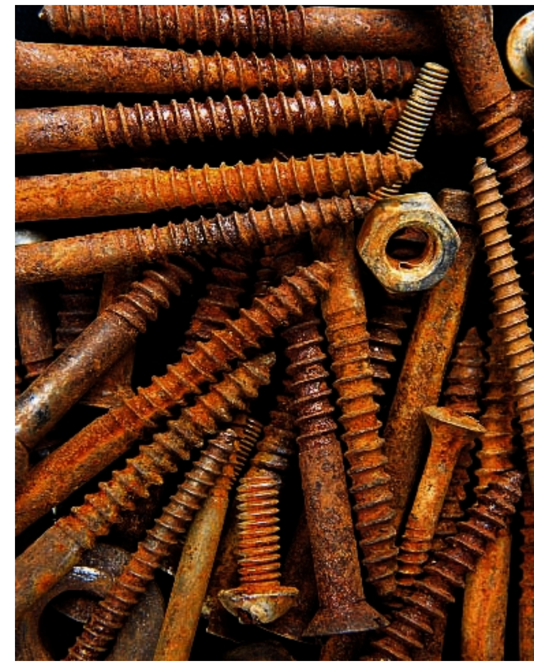
CHAPTER 4

- Some Types of Chemical Reactions



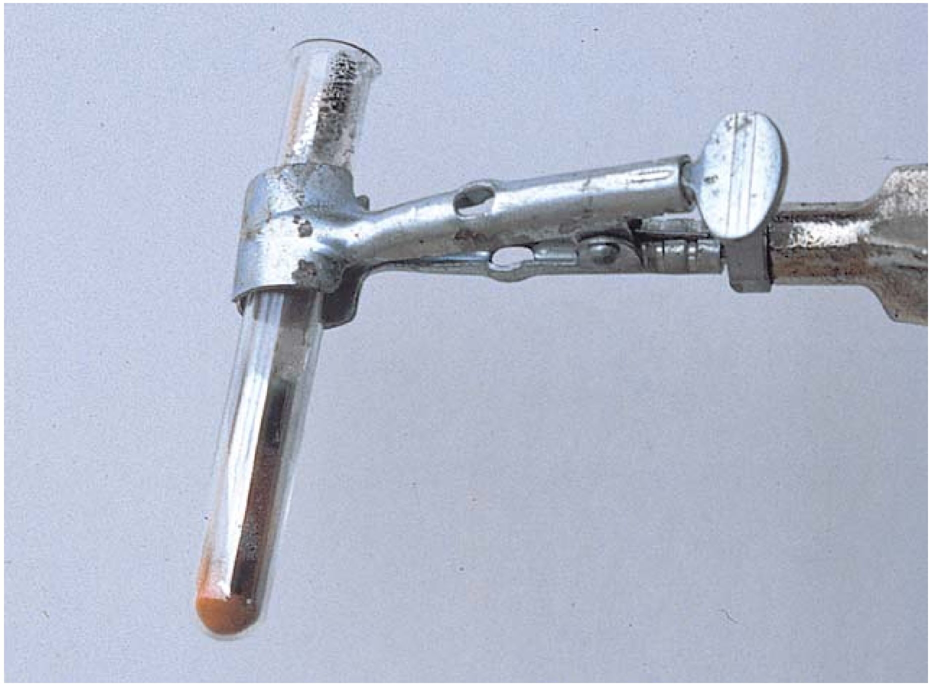
Types of Chemical Reactions





Rusting iron is a common example of a combination reaction, where two or more substances combine to form a new compound. rust is iron (III) oxide (Fe_2O_3) formed on these crews and bike from the combination of iron and oxygen under moist conditions.

Types of Chemical Reactions



Mercury (II) oxide is decomposed by heat, leaving the silver-colored element mercury behind as oxygen is driven off. This is an example of a decomposition reaction,

$$2\ HgO \rightarrow 2\ Hg + O_2\uparrow$$

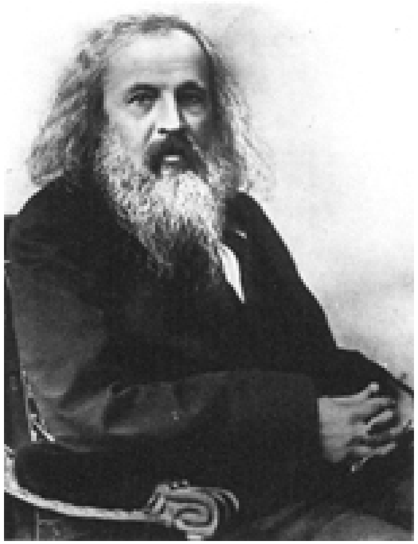
Chapter Goals

- The Periodic Table: Metals, Nonmetals, and Metalloids
- Aqueous Solutions: An Introduction
- Reactions in Aqueous Solutions
- Oxidation Numbers
- Naming Some Inorganic Compounds
- Classifying Chemical Reactions

The Periodic Table

Mendeleev & Meyer

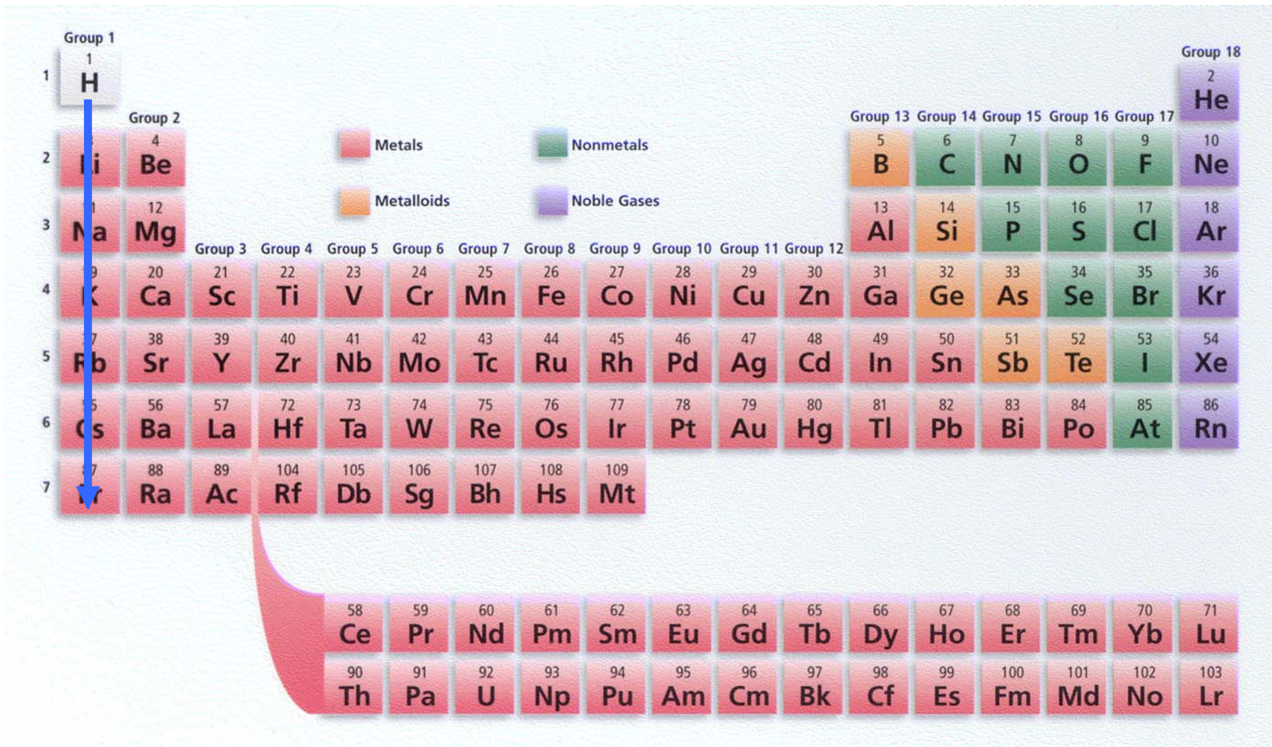
- **Discovered the periodic law**
  - **The properties of the elements are periodic functions of their atomic numbers.**



Dmitri Mendeleev

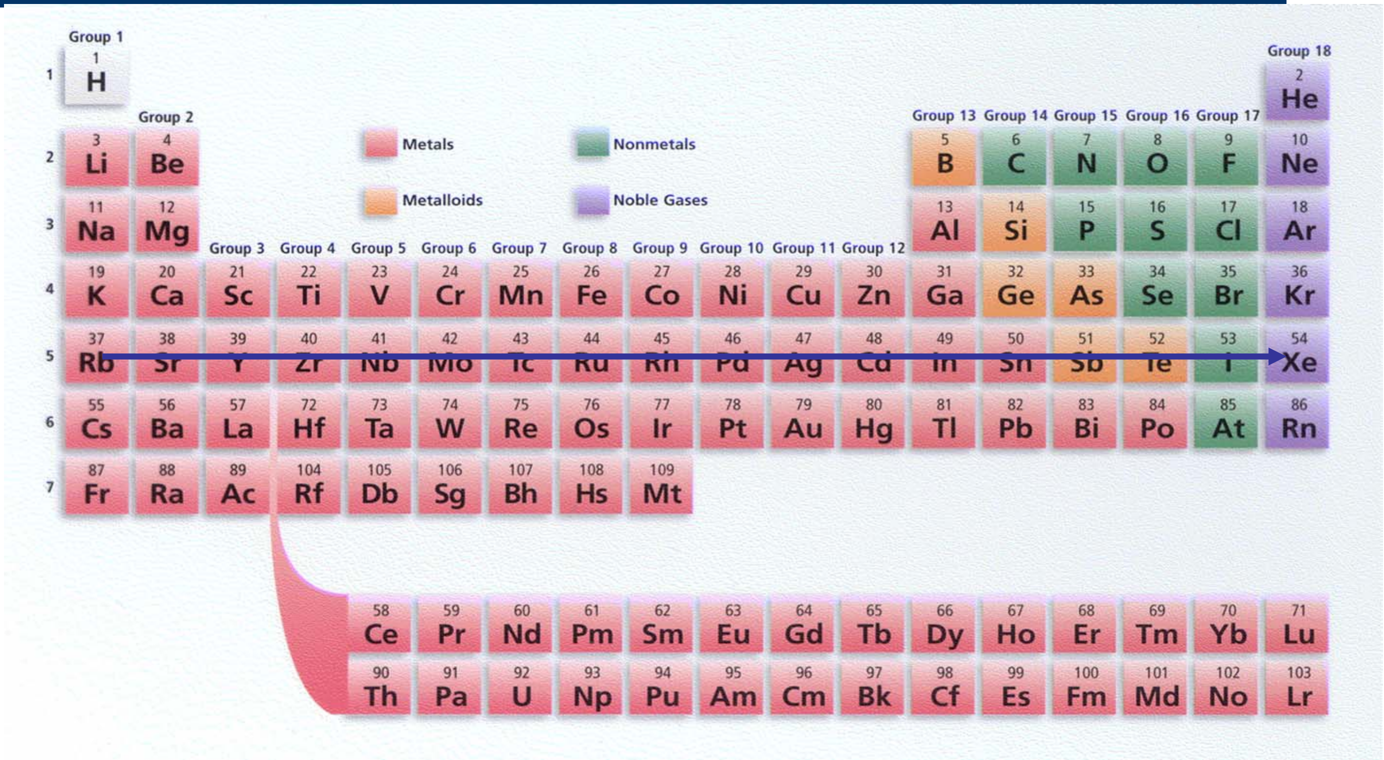
Lothar Meyer

Groups or Families



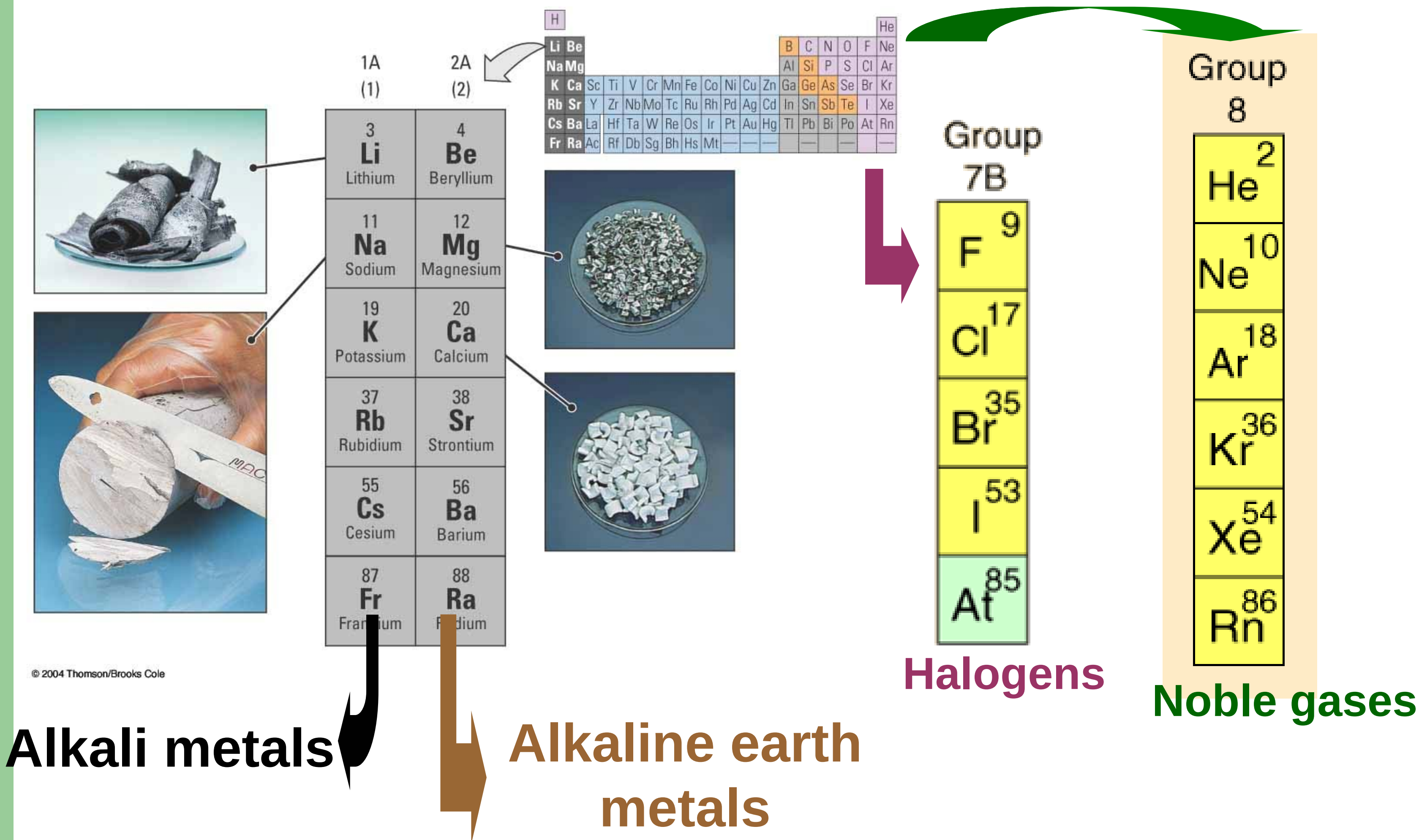
Vertical Columns: **referred to as groups or families and have similar chemical and physical properties (e.g. similar kinds of reactions, and similar kinds of compounds).**

Periods or Series



Horizontal Rows: **called periods or series and have properties that change progressively across the table (transition from metals to nonmetals).**

Alkali and alkaline earth metals



Periodic Table

TABLE 4-3 *Some Physical Properties of Metals and Nonmetals*

Metals	Nonmetals
1. High electrical conductivity that decreases with increasing temperature	1. Poor electrical conductivity (except carbon in the form of graphite)
2. High thermal conductivity	2. Good heat insulators (except carbon in the form of diamond)
3. Metallic gray or silver luster*	3. No metallic luster
4. Almost all are solids†	4. Solids, liquids, or gases
5. Malleable (can be hammered into sheets)	5. Brittle in solid state
6. Ductile (can be drawn into wires)	6. Nonductile

TABLE 4-4 *Some Chemical Properties of Metals and Nonmetals*

Metals	Nonmetals
1. Outer shells contain few electrons—usually three or fewer	1. Outer shells contain four or more electrons*
2. Form cations (positive ions) by losing electrons	2. Form anions (negative ions) by gaining electrons†
3. Form ionic compounds with nonmetals	3. Form ionic compounds with metals† and molecular (covalent) other compounds with nonmetals
4. Solid state characterized by metallic bonding	4. Covalently bonded molecules; noble gases are monatomic

The Periodic Table: Metals, Nonmetals, and Metalloids

- ***Some chemical properties of <u>metals</u>***

1. Outer shells contain <u>few electrons</u>
2. Form <u>cations</u> by losing electrons
3. Form <u>ionic compounds</u> with nonmetals
4. <u>Solid state</u> characterized by metallic bonding

Similar Reactions

Consider Group I: Li, Na, K, Rb, Cs

$Li + H_2O \rightarrow$ explosive gas, alkaline solution

$Na + H_2O \rightarrow$ explosive gas, alkaline solution

$K + H_2O \rightarrow$ explosive gas, alkaline solution

$Rb + H_2O \rightarrow$ explosive gas, alkaline solution

$Cs + H_2O \rightarrow$ explosive gas, alkaline solution

Requires warm water; sluggish

Vigorous in cool water; may explode

Explosion likely; very dangerous

Run! Call 911

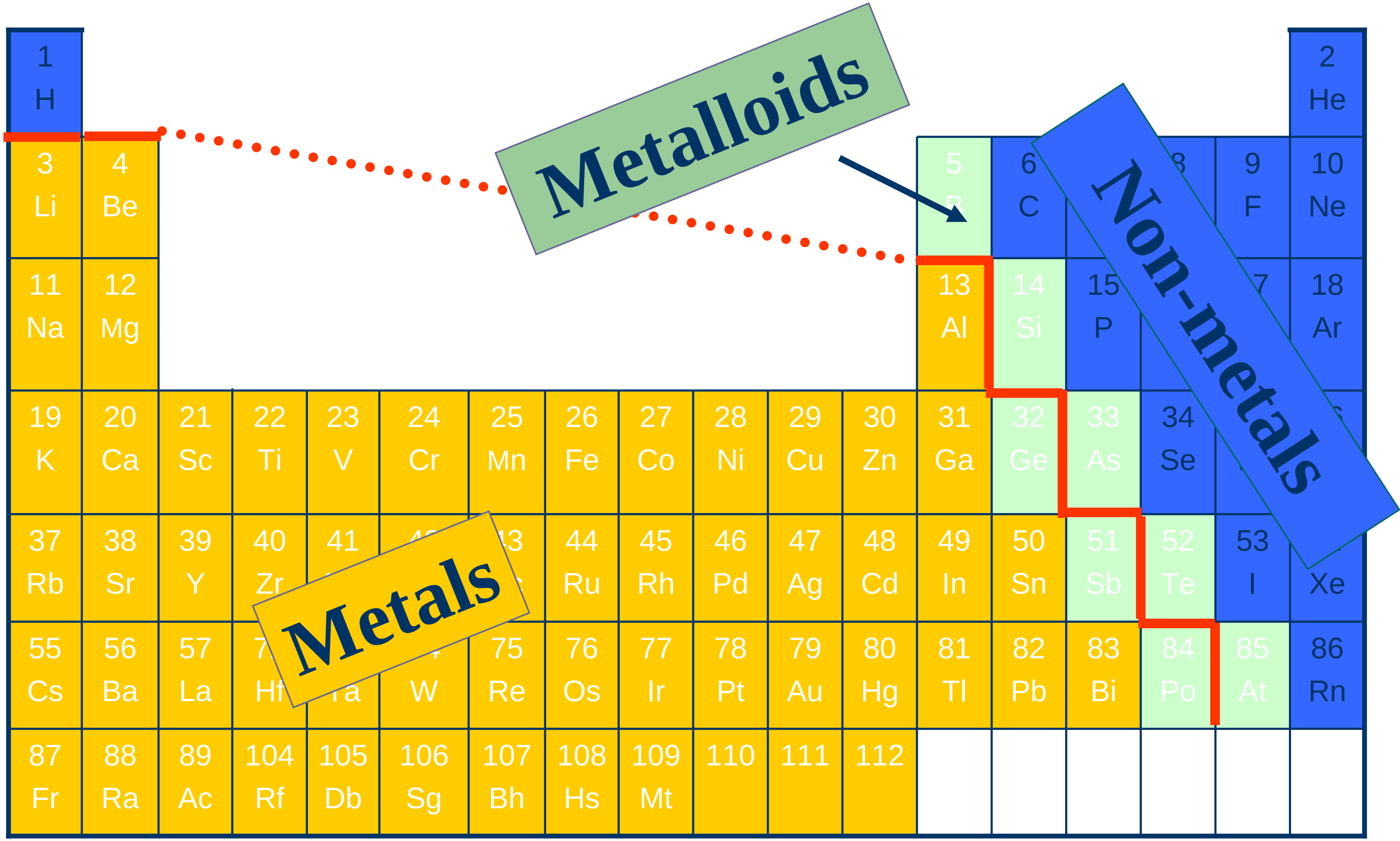
Our condolences.

The Periodic Table: Metals, Nonmetals, and Metalloids

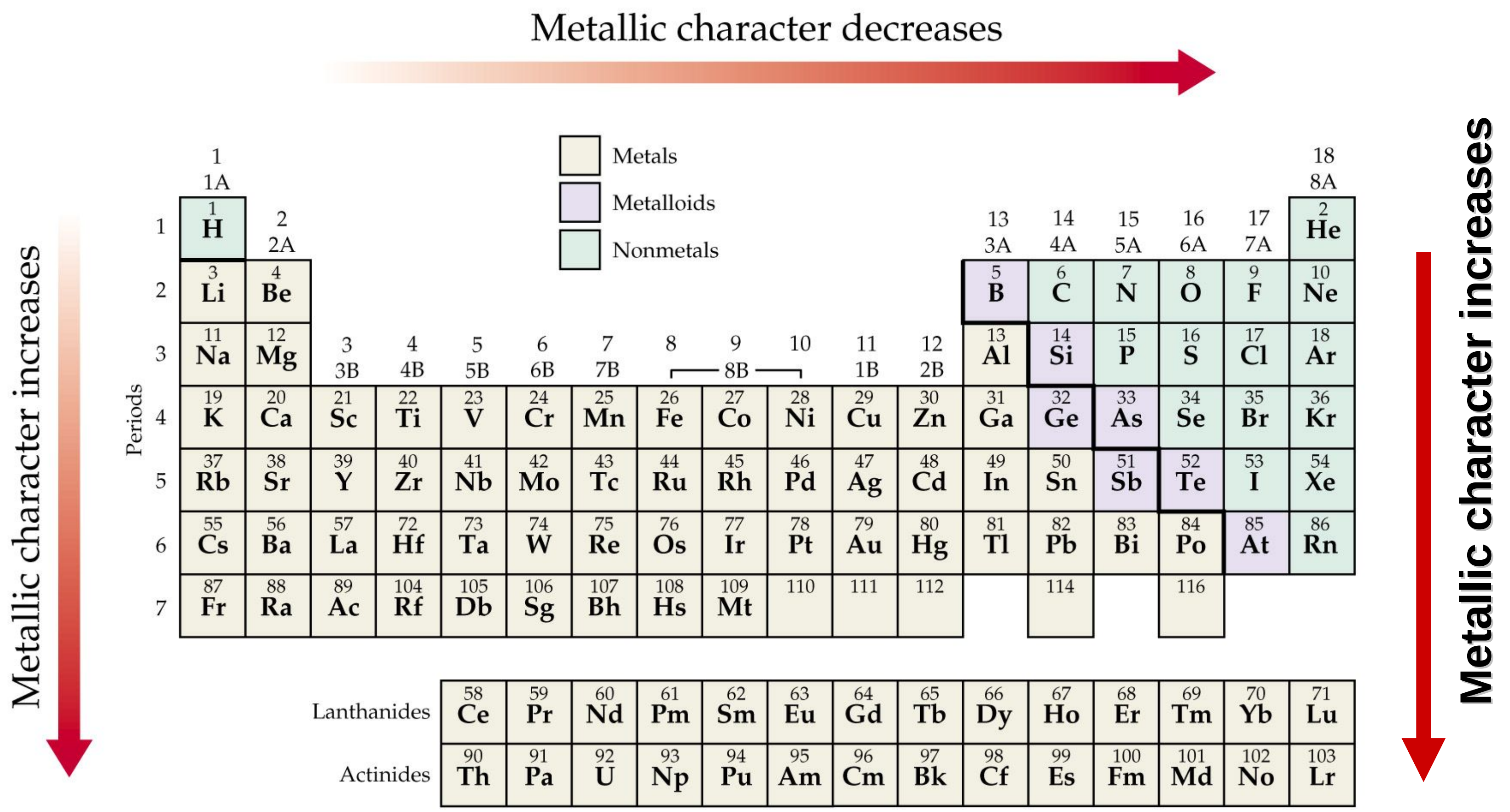
- ***Some chemical properties of <u>nonmetals</u>***

1. **Outer shells contain <u>four or more electrons</u>**
2. **Form <u>anions</u> by gaining electrons**
3. **Form <u>ionic compounds</u> with metals and covalent compounds with other nonmetals**
4. **Form <u>covalently bonded</u> molecules; noble gases are monatomic**

Metallic Character



Metallic Character



Aqueous Solutions: An Introduction

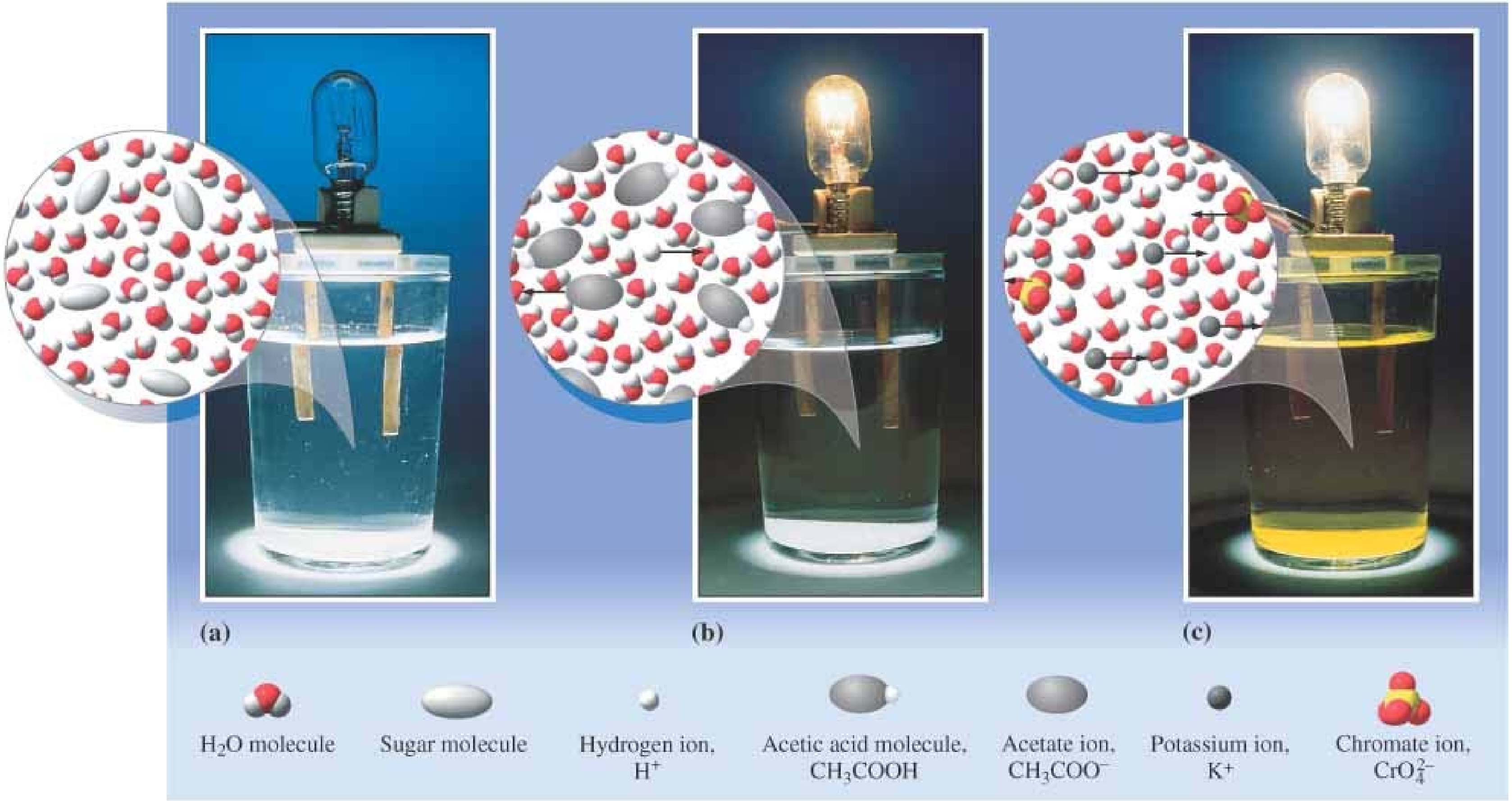
- **Many reactions take place in water-aqueous solution.**

- **It is important to know what happens to substances when they are placed in water.**
  1. Is it soluble in water?
  2. If it is soluble, does it break into ions?
  3. Terminology: acid, base, and salt

Aqueous Solutions: An Introduction

- **Electrolytes**
- Classification of solutes:
  - **Nonelectrolytes**: do not conduct electricity in water. The reason nonelectrolytes do not conduct electricity is because they do not form ions in solution. C_2H_5OH.
  - **Strong electrolytes**: conduct electricity extremely well in dilute aqueous solutions. HCl, HNO_3, NaOH, KOH, NaCl, KBr etc.
  - **Weak electrolytes** : conduct electricity poorly in dilute aqueous solutions. CH_3COOH.

Aqueous Solutions: An Introduction



Aqueous Solutions: An Introduction

1. <u>**Strong Acids**</u>

- **Acids are substances that generate H^+ in aqueous solutions. HCl, HBr, HI, HNO_3, H_2SO_4.**
- **Strong acids ionize 100% in water.**

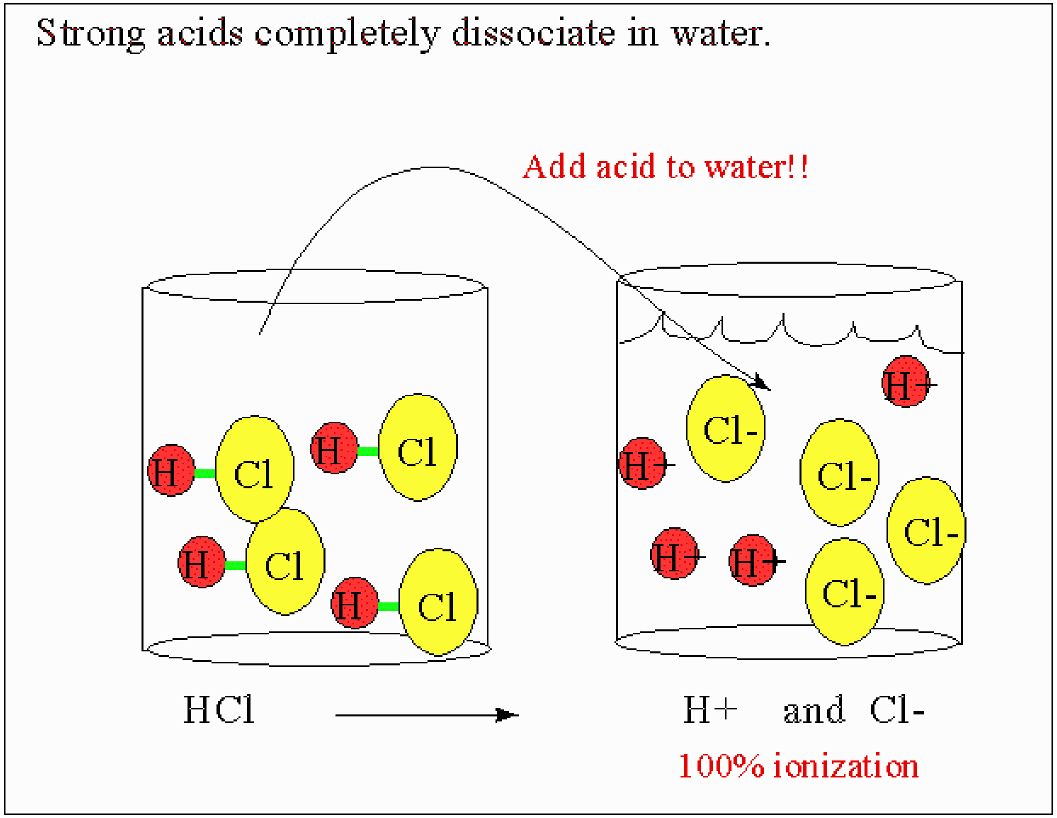
$$HCl_{(g)} \xrightarrow{\approx 100\%} H^+_{(aq)} + Cl^-_{(aq)}$$

$$HNO_3 + H_2O_{(\ell)} \xrightarrow{\approx 100\%} H_3O^+_{(aq)} + NO^-_{3(aq)}$$

or

$$HNO_3 \xrightarrow{H_2O} H^+_{(aq)} + NO^-_{3(aq)}$$

Aqueous Solutions: An Introduction



$$HCl_{(g)} \xrightarrow{\approx 100\%} H^{+}_{(aq)} + Cl^{-}_{(aq)}$$

Aqueous Solutions: An Introduction

- Some Strong Acids and Their Anions
- Formula Name

Formula	Name
1. HCl	hydrochloric acid
2. HBr	hydrobromic acid
3. HI	hydroiodic acid
4. HNO_3	nitric acid
5. H_2SO_4	sulfuric acid
6. $HClO_3$	chloric acid
7. $HClO_4$	perchloric acid

Aqueous Solutions: An Introduction

2. **Weak Acids**

- Weak acids ionize significantly less than 100% in water.

  HF, CH_3COOH, HCN, H_2CO_3, H_2SO_3, H_3PO_4.

- Typically ionize 10% or less!

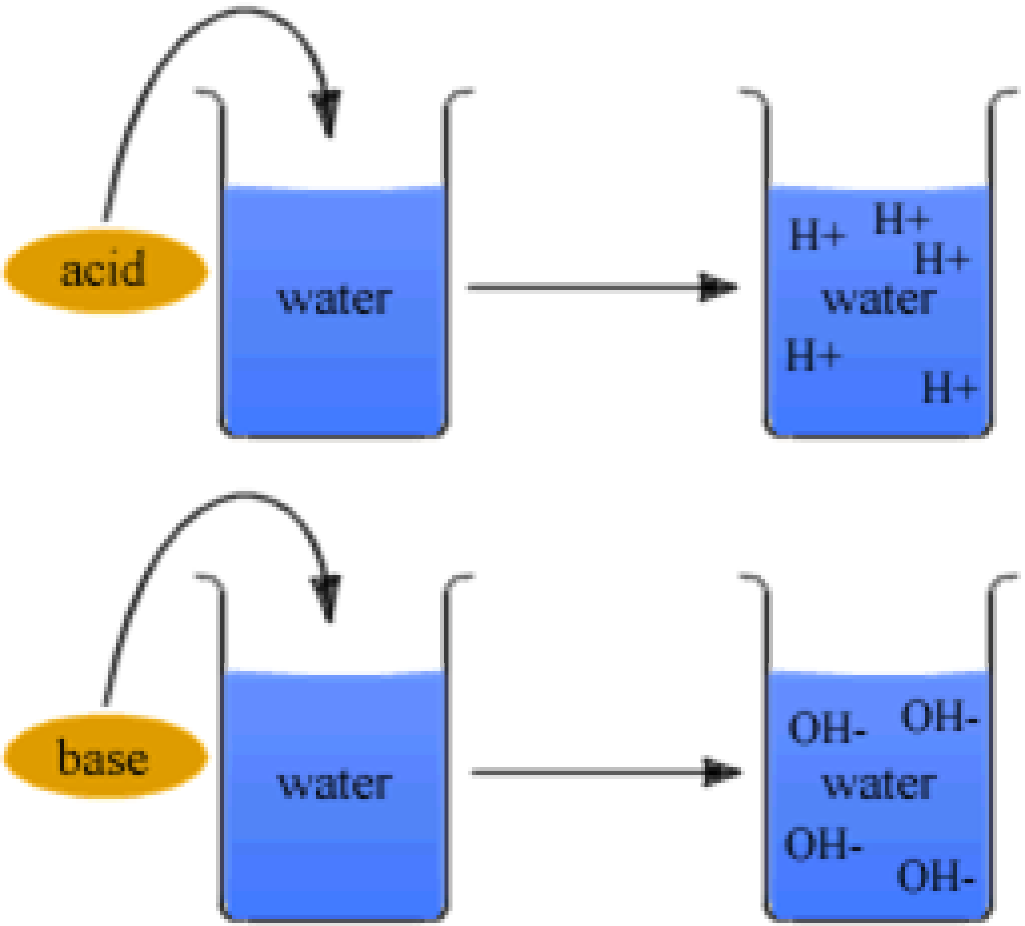
$$CH_3COOH \underset{}{\overset{\approx 7\%}{\rightleftharpoons}} CH_3COO^-_{(aq)} + H^+_{(aq)}$$

Aqueous Solutions: An Introduction

- **Some Common Weak Acids**
- **Formula** — **Name**

	Formula	Name
1.	HF	hydrofluoric acid
2.	CH_3COOH	acetic acid (vinegar)
3.	HCN	hydrocyanic acid
4.	HNO_2	nitrous acid
5.	H_2CO_3	carbonic acid (soda water)
6.	H_2SO_3	sulfurous acid
7.	H_3PO_4	phosphoric acid
8.	$(COOH)_2$	oxalic acid

Aqueous Solutions: An Introduction



Aqueous Solutions: An Introduction

3. <u>Strong Bases</u>

- Characteristic of common inorganic bases is that they produce OH^- ions in solution.
- $LiOH$, $NaOH$, KOH, $RbOH$, $CsOH$, $Ca(OH)_2$, $Sr(OH)_2$, $Ba(OH)_2$
- Similarly to strong acids, strong bases ionize 100% in water.

$$KOH \rightarrow K^+(aq) + OH^-(aq)$$

$$Ba(OH)_2 \rightarrow Ba^{2+}(aq) + 2\,OH^-(aq)$$

Aqueous Solutions: An Introduction

- **Common Strong Bases**
- **Formula** **Name**

1. LiOH lithium hydroxide
2. NaOH sodium hydroxide
3. KOH potassium hydroxide
4. RbOH rubidium hydroxide
5. CsOH cesium hydroxide
6. $Ca(OH)_2$ calcium hydroxide
7. $Sr(OH)_2$ strontium hydroxide
8. $Ba(OH)_2$ barium hydroxide

- Notice that they are all hydroxides of IA and IIA metals

Aqueous Solutions: An Introduction

4. **Insoluble or sparingly soluble bases**

- Ionic compounds that are insoluble in water, consequently, not very basic.

- **Formula** / **Name**

Formula	Name
1. $Cu(OH)_2$	copper (II) hydroxide
2. $Fe(OH)_2$	iron (II) hydroxide
3. $Fe(OH)_3$	iron (III) hydroxide
4. $Zn(OH)_2$	zinc (II) hydroxide
5. $Mg(OH)_2$	magnesium hydroxide

Aqueous Solutions: An Introduction

5. **Weak bases** are covalent compounds that ionize slightly in water.

- Ammonia is most common weak base

$$NH_{3\,(g)} + H_2O_{(\ell)} \rightleftarrows NH_{4\,(aq)}^{+} + OH^{-}_{(aq)}$$

Solubility Guidelines for Compounds in Aqueous Solutions

Solubility: A compound that dissolves in water to an appreciable extent is "soluble"; if not, it is "insoluble"

Solubility Rules: rule 1 to rule 8

It is very important that you know these guidelines and how to apply them in reactions.

Solubility Guidelines for Compounds in Aqueous Solutions

1- Common inorganic acids and low-molecular-weight organic acids are water **soluble**. High-molecular-weight organic acids are water **insoluble**.

2- All common compounds of the Group IA metal ions, Li^+, Na^+, K^+, Rb^+, Cs^+, and the ammonium ion, NH_4^+ ,are water **soluble**.

Solubility Guidelines for Compounds in Aqueous Solutions

3- Common nitrates, acetates, chlorates, and perchlorates are water soluble.

- NO_3^-, CH_3COO^-, ClO_3^-, and ClO_4^-

4- (a) Common chlorides, Cl^-, are water soluble.

- Exceptions – $AgCl$, Hg_2Cl_2, & $PbCl_2$

(b) Common bromides, Br^-, and iodides, I^-, behave similarly to chlorides.

(c) Common fluorides, F^-, are water soluble.

- Exceptions – MgF_2, CaF_2, SrF_2, BaF_2, and PbF_2

Solubility Guidelines for Compounds in Aqueous Solutions

5- Common sulfates, SO_4^{2-}, are water soluble.

- Exceptions – $PbSO_4$, $BaSO_4$, & $HgSO_4$
- Moderately soluble – $CaSO_4$, $SrSO_4$,& Ag_2SO_4

6- Common metal hydroxides, OH^-, are water insoluble.

- Exceptions: group IA metals, LiOH, NaOH, KOH, RbOH & CsOH
- Exceptions: group IIA metals, beginning with $Ca(OH)_2$, $Sr(OH)_2$, and $Ba(OH)_2$

Solubility Guidelines for Compounds in Aqueous Solutions

7- Common carbonates, CO_3^{2-}, phosphates, PO_4^{3-}, and arsenates, AsO_4^{3-}, are water **insoluble**.

- Exceptions- group IA metals and NH_4^+ plus Ca to Ba
- Moderately soluble – $MgCO_3$

8- Common sulfides, S^{2-}, are water **insoluble**.

- Exceptions – group IA metals, group IIA metals, and NH_4^+

Reactions in Aqueous Solutions

- There are three ways to write reactions in aqueous solutions.

1. **Formula unit (molecular) equation:** shows all reactants & products in "molecular" form (**remember to balance**)

$$Zn_{(s)} + CuSO_{4(aq)} \rightarrow ZnSO_{4(aq)} + Cu_{(s)}$$

2. **Total ionic equation:** Show the ions and molecules as they exist in solution

$$Zn_{(s)} + Cu^{2+}_{(aq)} + SO^{2-}_{4(aq)} \rightarrow Zn^{2+}_{(aq)} + SO^{2-}_{4(aq)} + Cu_{(s)}$$

Reactions in Aqueous Solutions

3. **Net ionic equation: shows ions that participate in reaction and removes spectator ions.**

- **Spectator ions: represented as < >'s, do not participate in the reaction. The spectators can be cancelled off from both sides of the equation and the equation is reduced to the NET IONIC EQUATION.**

$$Zn_{(s)} + Cu^{2+}_{(aq)} + \cancel{\left\langle SO^{2-}_{4(aq)} \right\rangle} \rightarrow Zn^{2+}_{(aq)} + \cancel{\left\langle SO^{2-}_{4(aq)} \right\rangle} + Cu_{(s)}$$

$$Zn_{(s)} + Cu^{2+}_{(aq)} \rightarrow Zn^{2+}_{(aq)} + Cu_{(s)}$$

Reactions in Aqueous Solutions

Molecular equation

$$2\,HCl_{(aq)} + Na_2SO_{3(aq)} \rightarrow 2\,NaCl_{(aq)} + H_2O_{(\ell)} + SO_{2(g)}$$

Total ionic reaction

$$2\,H^{1+}_{(aq)} + \cancel{2\,Cl^{1-}_{(aq)}} + \cancel{2\,Na^{1+}_{(aq)}} + SO^{2-}_{3(aq)} \rightarrow$$

$$\cancel{2\,Na^{1+}_{(aq)}} + \cancel{2\,Cl^{1-}_{(aq)}} + H_2O_{(\ell)} + SO_{2(g)}$$

Net ionic reaction

$$2\,H^{1+}_{(aq)} + SO^{2-}_{3(aq)} \rightarrow H_2O_{(\ell)} + SO_{2(g)}$$

Reactions in Aqueous Solutions

Molecular equation

$$Ca(OH)_{2(aq)} + 2\,HNO_{3(aq)} \rightarrow Ca(NO_3)_{2(aq)} + 2\,H_2O_{(\ell)}$$

Total ionic equation

$$\cancel{Ca^{2+}_{(aq)}} + 2\,OH^{-}_{(aq)} + 2\,H^{+}_{(aq)} \cancel{+ 2\,NO^{-}_{3(aq)}} \rightarrow \cancel{Ca^{2+}_{(aq)}} \cancel{+ 2\,NO^{-}_{3(aq)}} + 2\,H_2O_{(\ell)}$$

Net ionic equation

$$2\,OH^{-}_{(aq)} + 2\,H^{+}_{(aq)} \rightarrow 2\,H_2O_{(\ell)}$$

or better

$$OH^{-}_{(aq)} + H^{+}_{(aq)} \rightarrow H_2O_{(\ell)}$$

Reactions in Aqueous Solutions

Molecular equation

$$Ca(NO_3)_{2(aq)} + K_2CO_{3(aq)} \rightarrow 2\,KNO_{3(aq)} + CaCO_{3(s)}$$

Total ionic reaction

$$Ca^{2+}_{(aq)} + \cancel{2\,NO^{-}_{3(aq)}} \cancel{+ 2\,K^{+}_{(aq)}} + CO^{2-}_{3(aq)} \rightarrow$$

$$\cancel{2\,K^{+}_{(aq)}} + \cancel{2\,NO^{-}_{3(aq)}} + CaCO_{3(s)}$$

Net ionic reaction

$$\boxed{Ca^{2+}_{(aq)} + CO^{2-}_{3(aq)} \rightarrow CaCO_{3(s)}}$$

Reactions in Aqueous Solutions

Molecular equation

$$3\,CaCl_{2(aq)} + 2\,Na_3PO_{4(aq)} \rightarrow 6\,NaCl_{(aq)} + Ca_3(PO_4)_{2(s)}$$

Total ionic reaction

$$3\,Ca^{2+}_{(aq)} + \cancel{6\,Cl^{1-}_{(aq)}} + \cancel{6\,Na^{1+}_{(aq)}} + 2\,PO^{3-}_{4(aq)} \rightarrow$$

$$\cancel{6\,Na^{1+}_{(aq)}} + \cancel{6\,Cl^{1-}_{(aq)}} + Ca_3(PO_4)_{2(s)}$$

Net ionic reaction

$$\boxed{3\,Ca^{2+}_{(aq)} + 2\,PO^{3-}_{4(aq)} \rightarrow Ca_3(PO_4)_{2(s)}}$$

Oxidation Numbers

- **Many reactions, called oxidation-reduction or redox reactions, involve the transfer of electrons from 1 species to another.**

- **In order to keep track of the number of electrons lost or gained during a redox reaction, the concept of oxidation number is used.**

Oxidation Numbers

- **Guidelines for assigning oxidation numbers:**

1. **The oxidation number of any free, uncombined element is zero.**

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

2. **The oxidation number of an element in a simple (monatomic) ion is the charge on the ion.**

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

Oxidation Numbers

3. In the formula for any compound, the ***sum*** of the oxidation numbers of all elements in the compound is **zero**.

4. In a polyatomic ion, the ***sum*** of the oxidation numbers of the constituent elements is equal to the charge on the ion.

Oxidation Numbers

5. **Fluorine, F, has an oxidation number of –1 in its compounds.**

6. **Hydrogen, H, has an oxidation number of +1 unless it is combined with metals, where it has the oxidation number -1.**
   – **Examples – LiH, BaH_2**

7. **Oxygen, O, usually has the oxidation number -2.**
   – **Exceptions:**
   – **In peroxides O has oxidation number of –1.**
      - **Examples - H_2O_2, CaO_2, Na_2O_2**
   – **In OF_2 O has oxidation number of +2.**

Oxidation Numbers

8. Use the periodic table to help with assigning oxidation numbers of other elements.
   a. IA metals have oxidation numbers of +1.
   b. IIA metals have oxidation numbers of +2.
   c. IIIA metals have oxidation numbers of +3.
      - There are a few rare exceptions.
   d. VA elements have oxidation numbers of –3 in *binary* compounds with H, metals or NH_4^+.
   e. VIA elements below O have oxidation numbers of –2 in *binary* compounds with H, metals or NH_4^+.

- Summary in Table 4-10.

Oxidation Numbers

- Assign oxidation numbers to each element in the following compounds:

- N in $NaNO_3$
- Sn in $K_2Sn(OH)_6$
- S in SO_3^{2-}
- N in NH_3
- P in $H_4P_2O_7$
- Li in LiH
- C in HCO_3^-
- B in BO_3^-
- P in H_3PO_4
- Cr in $Cr_2O_7^{2-}$
- Fe
- Hg in Hg_2Cl_2
- S in $S_4O_6^{2-}$
- C in C_6H_6

Oxidation Numbers

- $NaNO_3$
- Na = +1 (Rule 8)
- O = -2 (Rule 7)
- N = +5
  - Calculate using rule 3.

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

  $x = +5$

Oxidation Numbers

- $K_2Sn(OH)_6$
- K = +1 (Rule 8)
- O = -2 (Rule 7)
- H = +1 (Rule 6)
- Sn = +5
  - Calculate using rule 3.

$$2(+1) + 6(-2) + 6(+1) + x = 0$$

$$x = +5$$

Oxidation Numbers

- SO_3^{2-}
- O = -2 (Rule 7)
- S = +4
  - Calculate using rule 4.

  $3(-2) + x = -2$

  $x = +4$

Oxidation Numbers

- $Cr_2O_7^{2-}$

You do it!

- O = -2
- Cr = +6

Oxidation number

HCO_3^-

O = -2   H = +1

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

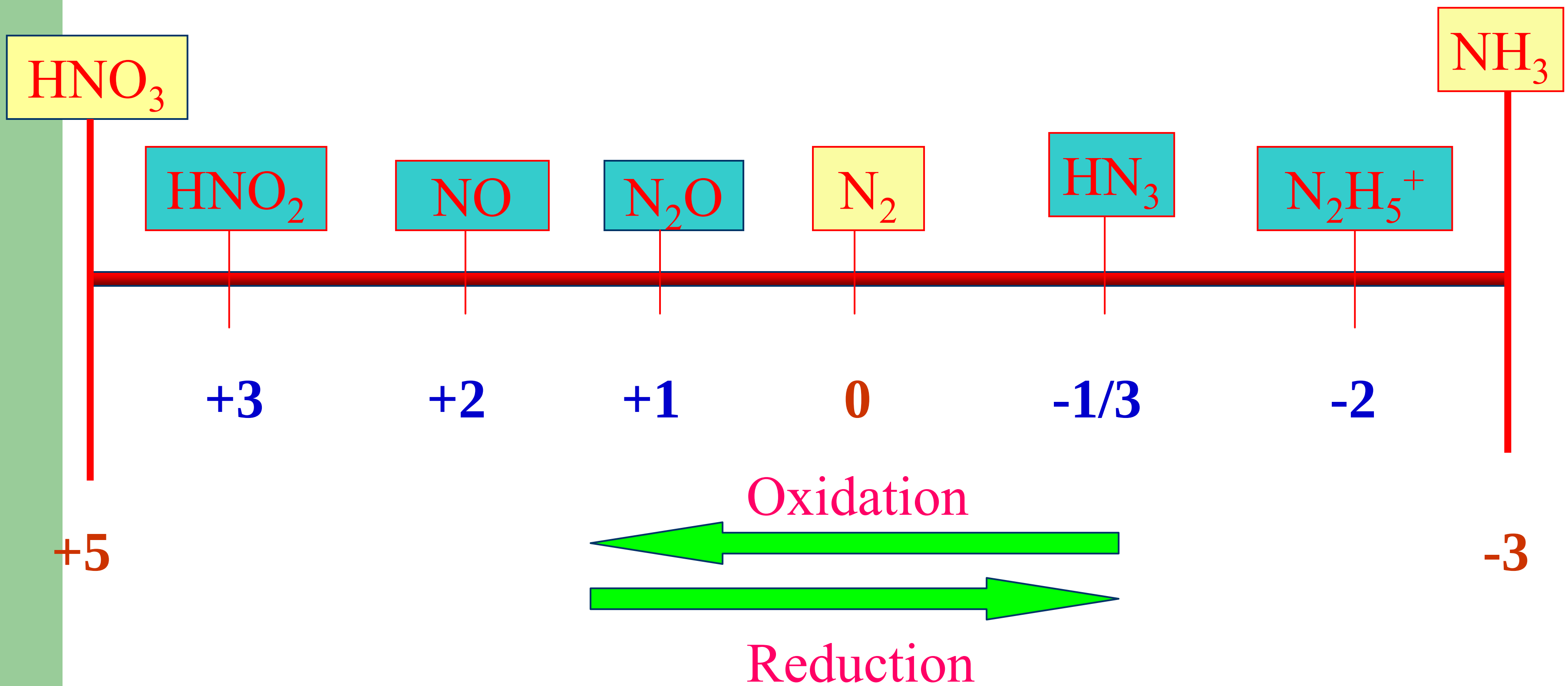
C = +4

Oxidation Numbers

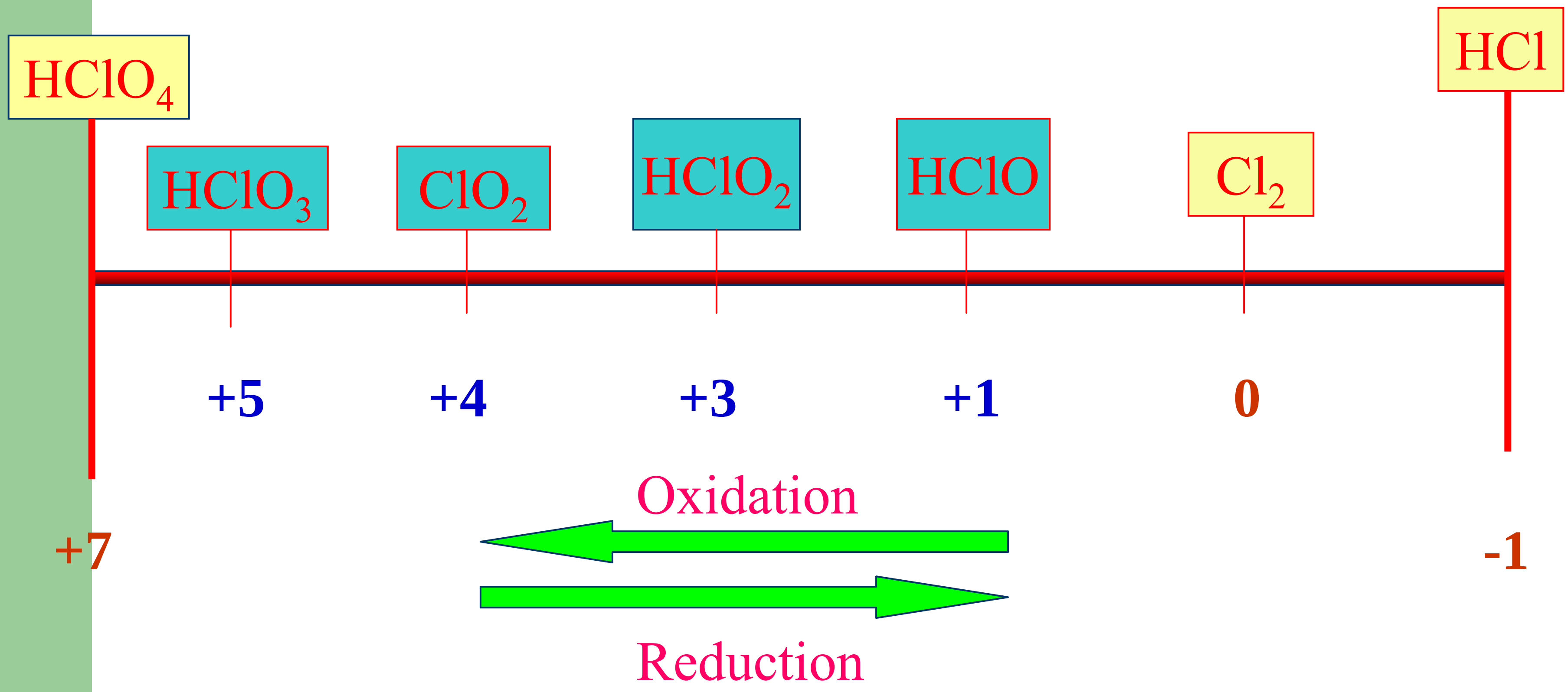
- Assign oxidation numbers to each element in the following compounds:

- N in $NaNO_3$
- Sn in $K_2Sn(OH)_6$
- S in SO_3^{2-}
- N in NH_3 (N = -3)
- P in $H_4P_2O_7$ (P = +5)
- Li in LiH (Li = +1)
- C in HCO_3^-
- B in BO_3^- (B = +5)
- P in H_3PO_4 (P = +5)
- Cr in $Cr_2O_7^{2-}$ (Cr = +6)
- Fe (Fe = 0)
- Hg in Hg_2Cl_2 (Hg = +1)
- S in $S_4O_6^{2-}$ (S = +2.5)
- C in C_6H_6 (C = -1)

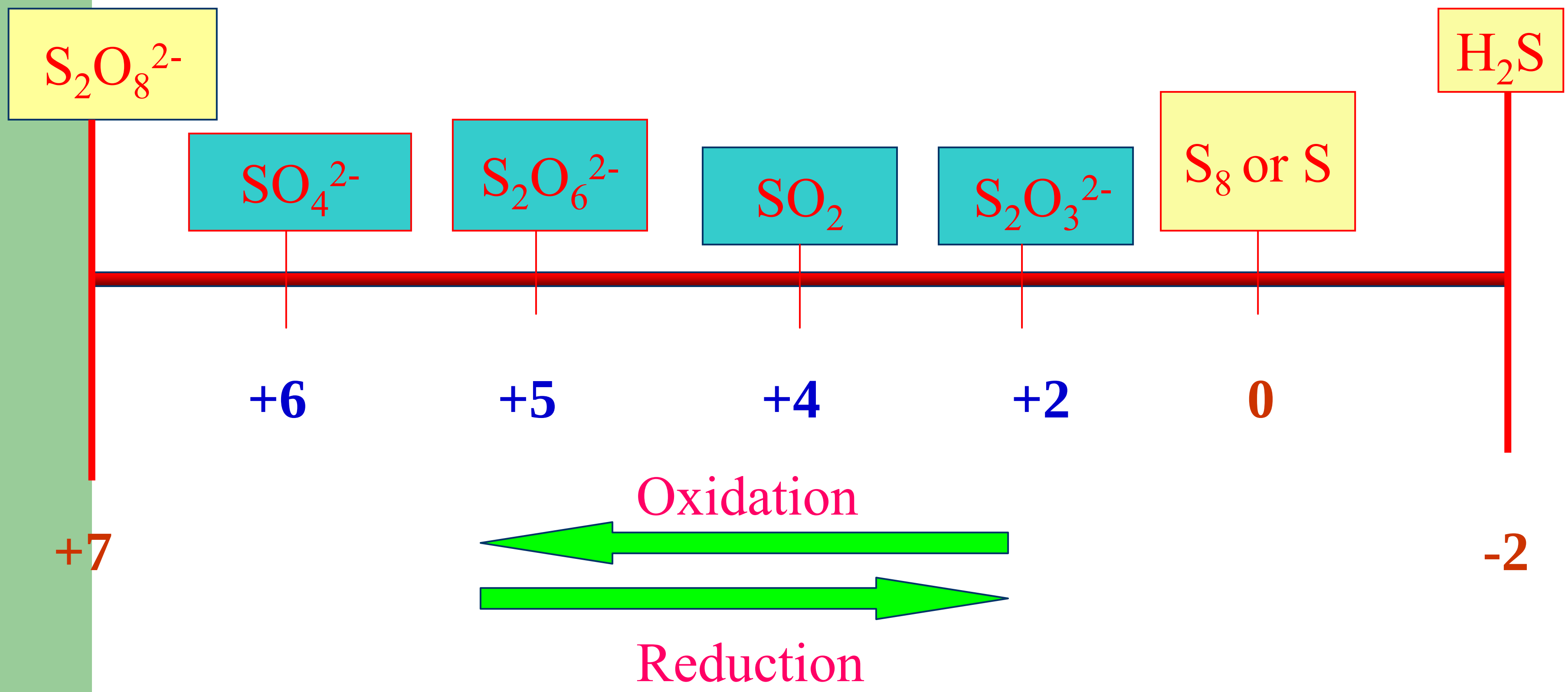
Oxidation States of Nitrogen



Oxidation States of Chlorine



Oxidation States of Sulfur



Naming Some Inorganic Compounds

- **This is definitely IMPORTANT!**
- ***Binary compounds*** **are made of two elements.**
  - **metal + nonmetal = ionic compound**
  - **nonmetal + nonmetal = covalent compound**
- **Name the more metallic element first.**
  - **Use the element's name.**
- **Name the less metallic element second.**
  - **Add the suffix "ide" to the element's stem.**

Naming Some Inorganic Compounds

- **Binary Ionic Compounds** are made of a metal cation and a nonmetal anion.
  - Cation named first
  - Anion named second
- LiBr lithium bromide
- $MgCl_2$ magnesium chloride
- Li_2S lithium sulfide
- Al_2O_3 aluminum oxide
- Na_3P sodium phosphide
- Mg_3N_2 magnesium nitride

Naming Some Inorganic Compounds

- Binary ionic compounds containing metals that exhibit more than one oxidation state
- Metals exhibiting multiple oxidation states are:
  1. most of the transition metals
  2. metals in groups IIIA (except Al), IVA, & VA

Naming Some Inorganic Compounds

- There are two methods to name these compounds.

1. **Older method**
   - add suffix "ous" to element's Latin name for lower oxidation state
   - add suffix "ic" to element's Latin name for higher oxidation state
2. **Modern method**
   - use Roman numerals in parentheses to indicate metal's oxidation state

Naming Some Inorganic Compounds

Compound	Old System	Modern System
$FeBr_2$	ferrous bromide	iron(II) bromide
$FeBr_3$	ferric bromide	iron(III) bromide
SnO	stannous oxide	tin(II) oxide
SnO_2	stannic oxide	tin(IV) oxide
$TiCl_2$	titanous chloride	titanium(II) chloride
$TiCl_3$	titanic chloride	titanium(III) chloride
$TiCl_4$	does not work	titanium(IV) chloride

Naming Some Inorganic Compounds

- **Pseudobinary ionic compounds**
- **There are three polyatomic ions that commonly form binary ionic compounds.**

Anion

1. **OH^- hydroxide**
2. **CN^- cyanide**

Cation

1. **NH_4^+ ammonium**

- **Use binary ionic compound naming system.**

Naming Some Inorganic Compounds

KOH	potassium hydroxide
$Ba(OH)_2$	barium hydroxide
$Fe(OH)_2$	iron (II) hydroxide
$Fe(OH)_3$	iron (III) hydroxide
$Ba(CN)_2$	barium cyanide
NH_4CN	ammonium cyanide
$(NH_4)_2S$	ammonium sulfide
NH_4CN	ammonium cyanide

Naming Some Inorganic Compounds

- **Binary covalent molecular compounds** composed of **two nonmetals** other than hydrogen
  - Nomenclature must include prefixes that **specify the number of atoms** of each element in the compound.

Number	Prefix
2	di
3	tri
4	tetra
5	penta
6	hexa
7	hepta
8	octa
9	nona
10	deca

Naming Some Inorganic Compounds

Formula	Name
CO	(~~mono~~)carbon monoxide
CO_2	carbon dioxide
SO_3	sulfur trioxide
OF_2	oxygen difluoride
P_4O_6	tetraphosphorus hexoxide
P_4O_{10}	tetraphosphorus decoxide

Naming Some Inorganic Compounds

- The oxides of nitrogen illustrate why covalent compounds need prefixes and ionic compounds do not.

Formula	Old Name	Modern Name
N_2O	nitrous oxide	dinitrogen monoxide
NO	nitric oxide	nitrogen monoxide
N_2O_3	nitrogen trioxide	dinitrogen trioxide
NO_2	nitrogen dioxide	nitrogen dioxide
N_2O_4	nitrogen tetroxide	dinitrogen tetroxide
N_2O_5	nitrogen pentoxide	dinitrogen pentoxide

Naming Some Inorganic Compounds

- **Binary Acids** are binary compounds consisting of **hydrogen** and **a nonmetal** (group VIA element other than O or group VIIA elements).
- Compounds are usually gases at room temperature and pressure.
  - Nomenclature for the **gaseous** compounds is ***hydrogen (stem)ide***.
- When the compounds are **dissolved in water** they form **acidic solutions**.
  - Nomenclature for the acidic solutions is ***hydro (stem)ic acid***.

Naming Some Inorganic Compounds

Formula	Name	Aqueous solution
HF	hydrogen fluoride	hydrofluoric acid
HCl	hydrogen chloride	hydrochloric acid
HBr	hydrogen bromide	hydrobromic acid
H_2S	hydrogen sulfide	hydrosulfuric acid

Naming Some Inorganic Compounds

- **Ternary Acids and Their Salts** are made of three elements, **H, O, & a nonmetal**.
- Two of the compounds are chosen as the basis for the nomenclature system.
  - **Higher oxidation state** for nonmetal is named **(stem)ic acid**.
  - **Lower oxidation state** for nonmetal is named **(stem)ous acid**
- Salts are named based on the acids.
  - Anions of **-ic** acids make "**ate**" salts.
  - Anions of **-ous** acids make "**ite**" salts.

Naming Some Inorganic Compounds

TABLE 4-12 *Formulas of Some "-ic" Acids*

Periodic Group of Central Elements				
IIA	*IVA*	*VA*	*VIA*	*VIIA*
+3 H_3BO_3 boric acid	+4 H_2CO_3 carbonic acid	+5 HNO_3 nitric acid		
	+4 H_4SiO_4 silicic acid	+5 H_3PO_4 phosphoric acid	+6 H_2SO_4 sulfuric acid	+5 $HClO_3$ chloric acid
		+5 H_3AsO_4 arsenic acid	+6 H_2SeO_4 selenic acid	+5 $HBrO_3$ bromic acid
			+6 H_6TeO_6 telluric acid	+5 HIO_3 iodic acid

Memorize the names and formulas of these acids.

Naming Some Inorganic Compounds

Name	Formula
carbonic acid	H_2CO_3
nitric acid	HNO_3
boric acid	H_3BO_3
phosphoric acid	H_3PO_4
sulfuric acid	H_2SO_4
chloric acid	$HClO_3$
bromic acid	$HBrO_3$
iodic acid	HIO_3
silicic acid	H_4SiO_4

Naming Some Inorganic Compounds

- Salts are formed by the reaction of the acid with a strong base.

Acid	Salt
HNO_2 nitrous acid	$NaNO_2$ sodium nitrite
HNO_3 nitric acid	$NaNO_3$ sodium nitrate
H_2SO_3 sulfurous acid	Na_2SO_3 sodium sulfite
H_2SO_4 sulfuric acid	Na_2SO4 sodium sulfate
$HClO_2$ chlorous acid	$NaClO_2$ sodium chlorite
$HClO_3$ chloric acid	$NaClO_3$ sodium chlorate

Naming Some Inorganic Compounds

- **Acids that have a higher oxidation state than the "ic" acid are given the prefix "per".**
  - **These acids and salts will have one more O atom than the "ic" acid.**

- **Acids that have a lower oxidation state than the "ous" acid are given the prefix "hypo".**
  - **These acids and salts will have one less O atom than the "ic" acid.**

Naming Some Inorganic Compounds

Decreasing oxidation number of central atom ↓

Ternary Acid	Anion
*per*XXX*ic* acid	*per*XXX*ate*
XXX*ic* acid	XXX*ate*
XXX*ous* acid	XXX*ite*
*hypo*XXX*ous* acid	*hypo*XXX*ite*

Decreasing number of oxygen atoms on central atom ↓

Naming Some Inorganic Compounds

Increasing Oxid. # of chlorine atom

Acid	Na Salt
$HClO$ (Cl = +1)	$NaClO$
hypochlorous acid	sodium hypochlorite
$HClO_2$ (Cl = +3)	$NaClO_2$
chlorous acid	sodium chlorite
$HClO_3$ (Cl = +5)	$NaClO_3$
chloric acid	sodium chlorate
$HClO_4$ (Cl = +7)	$NaClO_4$
perchloric acid	sodium perchlorate

Increasing # of O atoms on Cl atom

Naming Some Inorganic Compounds

- **Acidic Salts** are made from ternary acids that retain one or more of their acidic hydrogen atoms.
  - Made from acid base reactions where there is an insufficient amount of base to react with all of the hydrogen atoms.
- Old system used the prefix "**bi**" to denote the hydrogen atom.
- Modern system uses **prefixes** and the word **hydrogen**.

Naming Some Inorganic Compounds

- $NaHCO_3$
  Old system sodium bicarbonate
  Modern system sodium hydrogen carbonate
- $KHSO_4$
  Old system potassium bisulfate
  Modern system potassium hydrogen sulfate
- KH_2PO_4
  Old system potassium *bis* biphosphate
  Modern system potassium dihydrogen phosphate
- K_2HPO_4
  Old system potassium biphosphate
  Modern system potassium hydrogen phosphate

Classifying Chemical Reactions

- Oxidation-Reduction Reactions (Redox reactions)
- Combination Reactions
- Decomposition Reactions
- Displacement Reactions
- Metathesis Reactions
- Acid-Base (neutralization) Reactions
- Precipitation reactions

Classifying Chemical Reactions

Reaction

Change in Oxidation State?

YES → **Redox**

NO → **Metathesis or Decomposition**

Redox:

- **Displacement:** $M + 2HCl \rightarrow MCl_2 + H_2(g)$
- **Decomposition:** $A \rightarrow B + C + \ldots$
- **Combination:** $A + B \rightarrow C$
- **Disproportionation:** $M^{+} \rightarrow M^{3+} + M^{0}$

Metathesis

- **Neutralization:** $H^{+} + OH^{-} \rightarrow H_2O$
- **Precipitation:** $Ag^{+} + Cl^{-} \rightarrow AgCl(s)$

Decomposition

No change in OS

Oxidation-Reduction Reactions

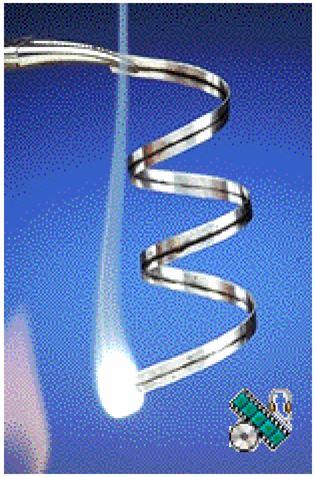
- **Oxidation** is an **increase** in the oxidation number.
  - Corresponds to the loss of electrons.
- **Reduction** is a **decrease** in the oxidation number.
  - Corresponds to the gain of electrons

Oxidation-Reduction Reactions

- Oxidizing agents are chemical species that:
  1. oxidize some other substance
  2. contain atoms that are reduced
  3. gain electrons
- Reducing agents are chemical species that:
  1. reduce some other substance
  2. contain atoms that are oxidized
  3. lose electrons

Oxidation-Reduction Reactions:

- Example of oxidation-reduction or redox reaction.
- Combustion reactions are redox reactions
- Combustion of Mg
  - Mg is oxidized to MgO
  - O_2 is reduced to O^{2-}



$$2Mg \quad + \quad O_2 \quad \rightarrow \quad 2MgO$$

Combination Reactions

- <u>**Combination reactions**</u> **occur when two or more substances combine to form a compound.**
- **There are three basic types of combination reactions.**
  1. **Two elements react to form a new compound**
  2. **An element and a compound react to form one new compound**
  3. **Two compounds react to form one compound**

Combination Reactions

1. **Element + Element → Compound**

A. **Metal + Nonmetal → Binary Ionic Compound**

$$2\ Na_{(s)} + Cl_{2(g)} \rightarrow 2\ NaCl_{(s)}$$

$$2\ Mg_{(s)} + O_{2(g)} \rightarrow 2\ MgO_{(s)}$$

B. **Nonmetal + Nonmetal → Covalent Binary Compound**

$$P_{4(s)} + 5\ O_{2(g)} \rightarrow P_4O_{10(s)}$$

$$P_{4(s)} + 6\ Cl_{2(g)} \rightarrow 4\ PCl_{3(\ell)}$$

Combination Reactions

2. **Compound + Element → Compound**

$$AsCl_{3(s)} + Cl_{2(g)} \rightarrow AsCl_{5(s)}$$

$$SF_{4(s)} + F_{2(g)} \rightarrow SF_{6(g)}$$

3. **Compound + Compound → Compound**

$$Li_2O + SO_2 \rightarrow Li_2SO_3$$

$$NH_{3(g)} + HCl_{(g)} \rightarrow NH_4Cl_{(s)}$$

Disproportionation Reactions

<u>**Disproportionation raction**</u> **is a redox reaction in which the same element is oxidized and reduced.**

$$4\overset{+1}{\mathrm{K}}\overset{+5}{\mathrm{Cl}}\overset{-2}{\mathrm{O}}_3(s) \longrightarrow \overset{+1}{\mathrm{K}}\overset{-1}{\mathrm{Cl}}(s) + 3\overset{+1}{\mathrm{K}}\overset{+7}{\mathrm{Cl}}\overset{-2}{\mathrm{O}}_4(s)$$

-6

$+2$

Decomposition Reactions

- **Decomposition reactions** occur when one compound decomposes to form:
  1. Two elements
  2. One or more elements and one or more compounds
  3. Two or more compounds

Decomposition Reactions

1. **Compound → Element + Element**

$$2\,N_2O_{(g)} \xrightarrow{\Delta} 2\,N_{2(g)} + O_{2(g)}$$

2. **Compound → Element + Compound(s)**

$$2\,H_2O_{2(aq)} \xrightarrow{h\nu \text{ or } Fe^{3+} \text{ or } Mn} 2\,H_2O_{(\ell)} + O_{2(g)}$$

3. **Compound → Compounds**

$$NH_4HCO_{3(s)} \xrightarrow{\Delta} NH_{3(g)} + H_2O_{(g)} + CO_{2(g)}$$

Displacement Reactions

- **Displacement reactions** occur when one element displaces another element from a compound.

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

$$2[\overset{+1}{Ag}{}^{+}(aq) + \overset{+5}{N}\overset{-2}{O}{}_3^{-}(aq)] + \overset{0}{Cu}(s) \longrightarrow [\overset{+2}{Cu}{}^{2+}(aq) + 2\overset{+5}{N}\overset{-2}{O}{}_3^{-}(aq)] + 2\overset{0}{Ag}(s)$$

$+2$

-1

$$2\overset{+1}{Ag}{}^{+}(aq) + \overset{0}{Cu}(s) \longrightarrow \overset{+2}{Cu}{}^{2+}(aq) + 2\overset{0}{Ag}(s)$$

Displacement Reactions

- **The following metals are active enough to displace hydrogen**
  - **K, Ca, Na, Mg, Al, Zn, Fe, Sn, & Pb**

$$2\,Al_{(s)} + 3H_2SO_{4(aq)} \rightarrow Al_2(SO_4)_{3(aq)} + 3\,H_{2(g)}$$

Displacement Reactions

- **Each halogen will displace less active (heavier) halogens from their binary salts; that is, the order of decreasing activities is**

$$\mathbf{F_2 > Cl_2 > Br_2 > I_2}$$

$$Cl_{2(g)} + 2\ NaI_{(aq)} \rightarrow I_{2(s)} + 2\ NaCl_{(aq)}$$

Metathesis Reactions

- **Metathesis reactions** occur when two ionic aqueous solutions are mixed and the ions switch partners.

  $$AX + BY \rightarrow AY + BX$$

- **Metathesis reactions remove ions from solution in two ways:**
  1. **form unionized molecules like H_2O**
  2. **form an insoluble solid**
- **Ion removal** is the driving force of metathesis reactions.

Metathesis Reactions

1. **Acid-Base (neutralization) Reactions**
   - **Formation of the nonelectrolyte H_2O**
   - **acid + base → salt + water**
   - **HCl + NaOH → NaCl + H_2O**

2. **Precipitation reactions are metathesis reactions in which an insoluble compound is formed.**

$$3\overset{+1}{Ag^+}(aq) + \overset{+5\;\,-2}{PO_4^{3-}}(aq) \longrightarrow \overset{+1\;\,+5\;\,-2}{Ag_3PO_4}(s)$$

Classifying Chemical Reactions

Which of the following is a reduction-oxidation (redox) reaction?

$FeCl_2(aq) + 2AgNO_3(aq) \rightarrow 2AgCl(s) + Fe(NO_3)_2(aq)$

$AgNO_3(aq) + NaBr(aq) \rightarrow AgBr(s) + NaNO_3(aq)$

$Zn(s) + 2AgNO_3(aq) \rightarrow 2Ag(s) + Zn(NO_3)_2(aq)$

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

$3HCl(aq) + Cr(OH)_3(s) \rightarrow CrCl_3(aq) + 3H_2O(l)$

Classifying Chemical Reactions

Which of the following reactions is a combination reaction?

(a) $AgNO_3(aq) + HCl(aq) \rightarrow AgCl(s) + HNO_3(aq)$

(b) $Na_2O(s) + CO_2(g) \rightarrow Na_2CO_3(s)$

(c) $C_3H_8(g) + 5O_2(g) \rightarrow 3CO_2(g) + 4H_2O(l)$

(d) $2H_2O(l) \rightarrow 2H_2(g) + O_2(g)$

(e) $KOH(aq) + HCl(aq) \rightarrow KCl(aq) + H_2O(l)$

Naming Compounds

Write formulas for the compounds that are expected to be formed by the following pairs of ions:

	A. Cl^-	B. OH^-	C. SO_4^{2-}	D. PO_4^{3-}	E. NO_3^-
1. NH_4^+		Omit – see note			
2. Na^+					
3. Mg^{2+}					
4. Ni^{2+}					
5. Fe^{3+}					
6. Ag^+					

Homework Assignment

One-line Web Learning (OWL):

Chapter 4 Exercises and Tutors – Required

Due by 03/08 (11:00 pm).