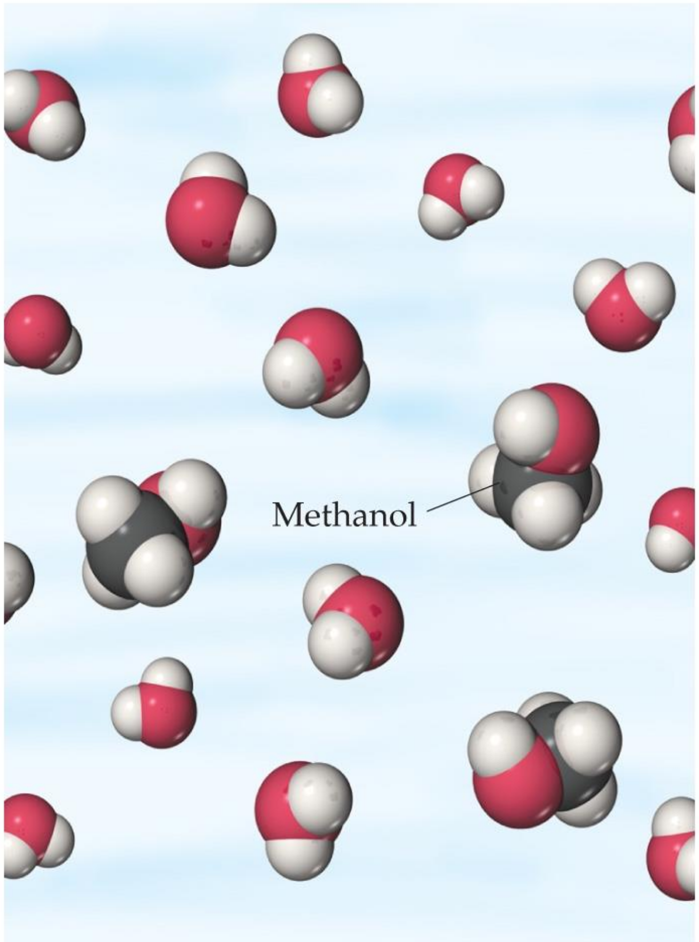
Chapter 4

Reactions in Aqueous Solution

Solutions

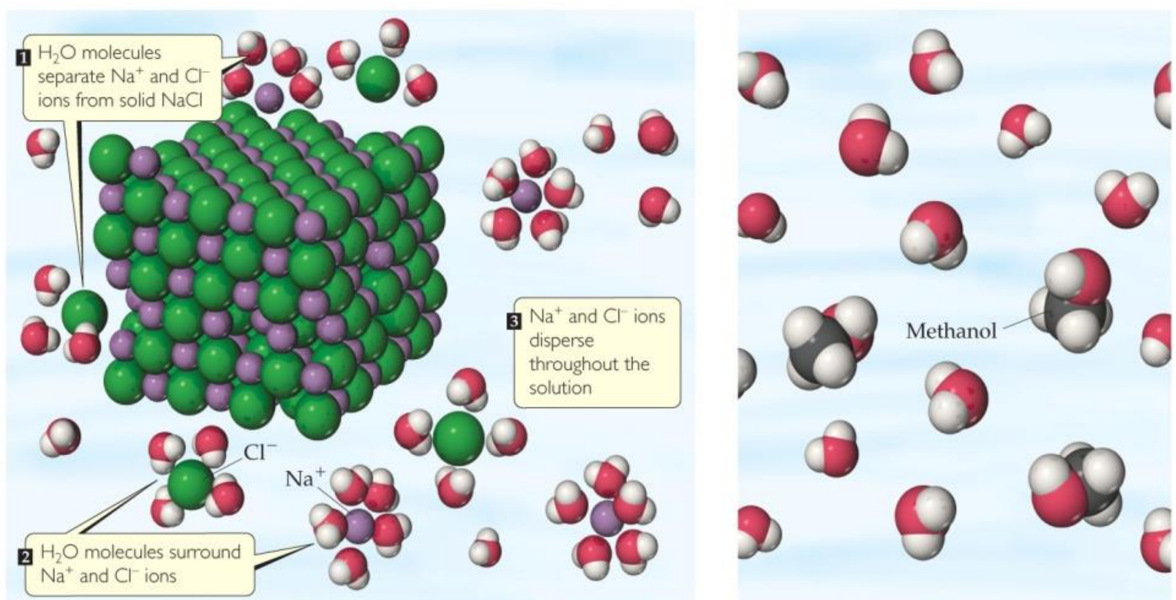


(b) Molecular substances like methanol, CH_3OH, dissolve without forming ions.

- **Solutions** are defined as homogeneous mixtures of two or more pure substances.
- The **solvent** is present in greatest abundance.
- All other substances are **solutes**.
- When water is the solvent, the solution is called an **aqueous solution**.

Aqueous Solutions

- Substances can dissolve in water by different ways:
  - Ionic Compounds dissolve by **dissociation (解离)**, where water surrounds the separated ions.
  - Molecular compounds interact with water, but most do NOT dissociate.
  - Some molecular substances react with water when they dissolve.



(a) Ionic compounds like sodium chloride, NaCl, form ions when they dissolve.

(b) Molecular substances like methanol, CH_3OH, dissolve without forming ions.

Electrolytes and Nonelectrolytes

Table 4.3 Summary of the Electrolytic Behavior of Common Soluble Ionic and Molecular Compounds

	Strong Electrolyte	Weak Electrolyte	Nonelectrolyte
Ionic	All	None	None
Molecular	Strong acids (see Table 4.2)	Weak acids, weak bases	All other compounds

- An **electrolyte** (电解质) is a substance that dissociates into ions when dissolved in water.
- A **nonelectrolyte** may dissolve in water, but it does not dissociate into ions when it does so.

Electrolytes

Pure water does not conduct electricity

An **nonelectrolyte solution** does not conduct electricity

An **electrolyte solution** conducts electricity

Pure water, $H_2O(l)$

Sucrose solution, $C_{12}H_{22}O_{11}(aq)$

Sodium chloride solution, $NaCl(aq)$

- A **strong electrolyte** dissociates completely when dissolved in water.
- A **weak electrolyte** only dissociates partially when dissolved in water.
- A **nonelectrolyte** does NOT dissociate in water.

Solubility of Ionic Compounds

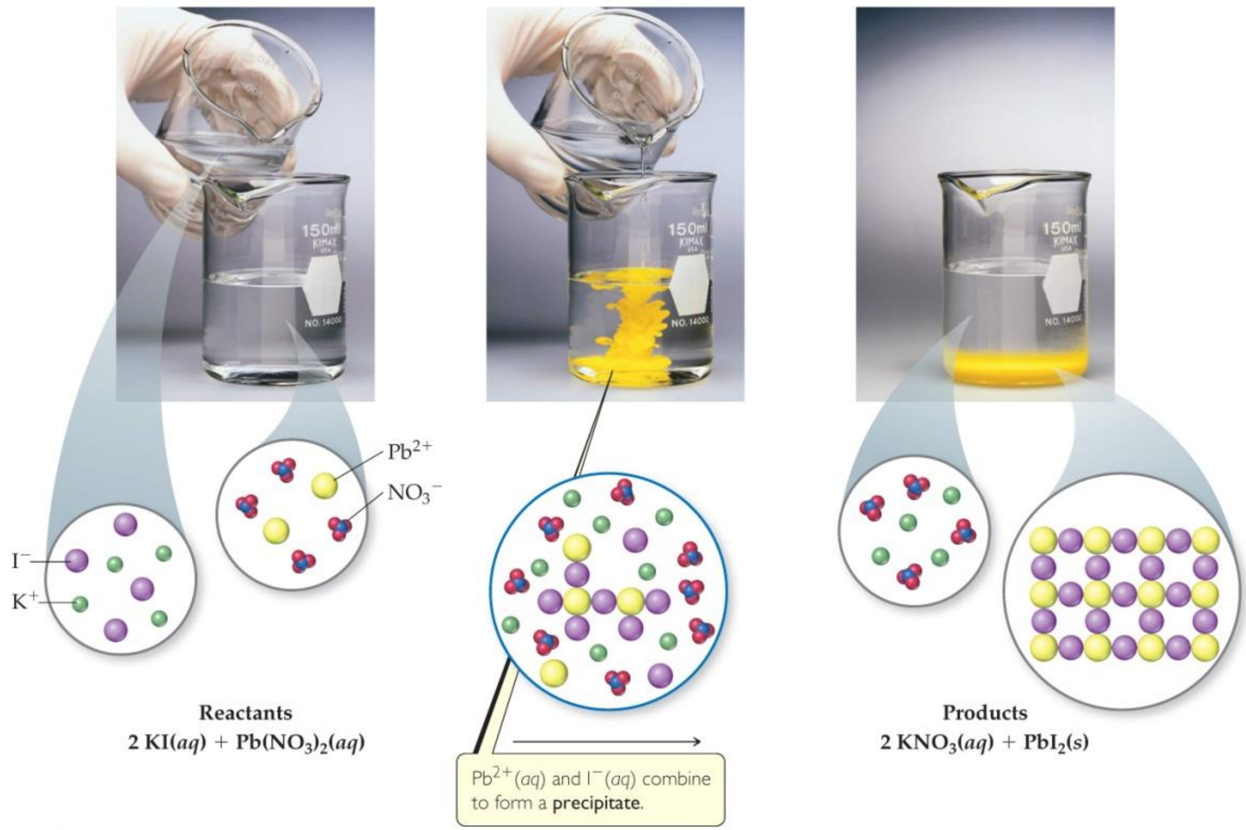
- **Not all ionic compounds dissolve in water**.
- A list of **solubility rules** is used to decide what combination of ions will dissolve.

Table 4.1 Solubility Guidelines for Common Ionic Compounds in Water

Soluble Ionic Compounds		Important Exceptions
Compounds containing	NO_3^-	None
	CH_3COO^-	None
	Cl^-	Compounds of Ag^+, Hg_2^{2+}, and Pb^{2+}
	Br^-	Compounds of Ag^+, Hg_2^{2+}, and Pb^{2+}
	I^-	Compounds of Ag^+, Hg_2^{2+}, and Pb^{2+}
	SO_4^{2-}	Compounds of Sr^{2+}, Ba^{2+}, Hg_2^{2+}, and Pb^{2+}
Insoluble Ionic Compounds		**Important Exceptions**
Compounds containing	S^{2-}	Compounds of NH_4^+, the alkali metal cations, Ca^{2+}, Sr^{2+}, and Ba^{2+}
	CO_3^{2-}	Compounds of NH_4^+ and the alkali metal cations
	PO_4^{3-}	Compounds of NH_4^+ and the alkali metal cations
	OH^-	Compounds of NH_4^+, the alkali metal cations, Ca^{2+}, Sr^{2+}, and Ba^{2+}

Precipitation Reactions

When two solutions containing soluble salts are mixed, sometimes an insoluble salt will be produced. A salt "falls" out of solution, like snow out of the sky. This solid is called a **precipitate(沉淀)**.



Metathesis (Exchange) Reactions
复分解反应

- Metathesis comes from a Greek word that means “to transpose.” 转置
- It appears as though the ions in the reactant compounds exchange, or transpose, ions, as seen in the equation below.

$$\mathbf{Ag}NO_3(aq) + K\mathbf{Cl}(aq) \longrightarrow \mathbf{AgCl}(s) + KNO_3(aq)$$

Completing and Balancing Metathesis Equations

- Steps to follow

1) Use the chemical formulas of the reactants to determine which ions are present.
2) Write formulas for the products: cation from one reactant, anion from the other. Use charges to write proper subscripts.
3) Check your solubility rules. If either product is insoluble, a precipitate forms.
4) Balance the equation.

Ways to Write Metathesis Reactions

1) Molecular equation
2) Complete ionic equation
3) Net ionic equation

Molecular Equation

The **molecular equation** lists the reactants and products without indicating the ionic nature of the compounds.

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

Complete Ionic Equation

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

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

Net Ionic Equation

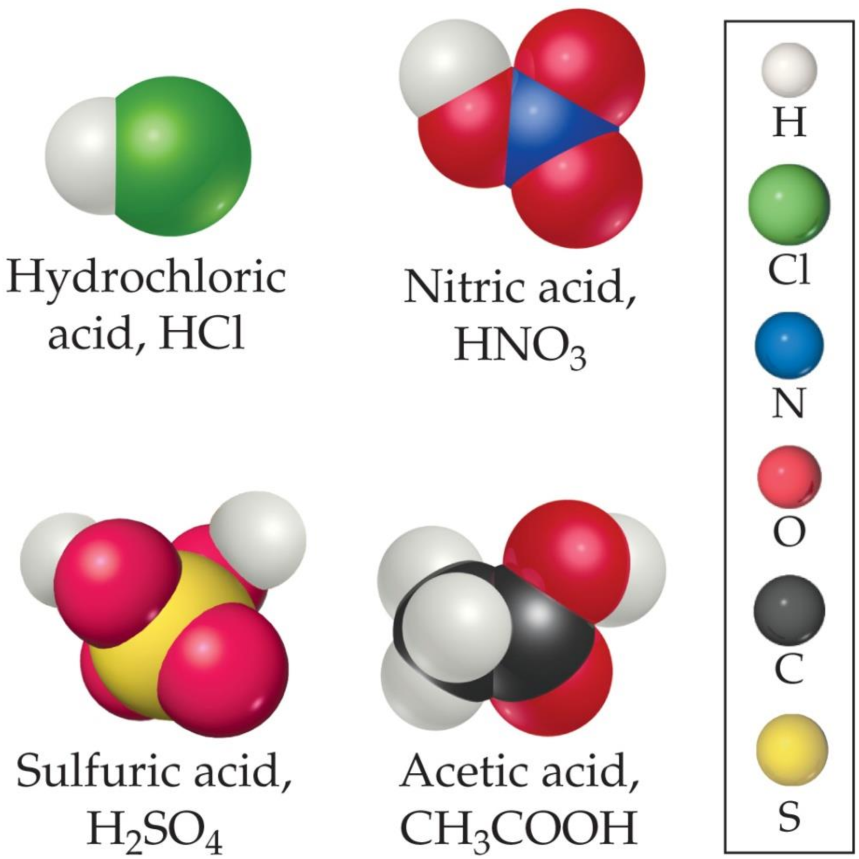
- To form the net ionic equation, cross out anything that does not change from the left side of the equation to the right.
- The ions crossed out are called **spectator ions**, K+ and NO_3^-, in this example.
- The remaining ions are the reactants that form the product—an insoluble salt in a precipitation reaction, as in this example.

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

Writing Net Ionic Equations

1. Write a balanced molecular equation.
2. Dissociate all strong electrolytes.
3. Cross out anything that remains unchanged from the left side to the right side of the equation.
4. Write the net ionic equation with the species that remain.

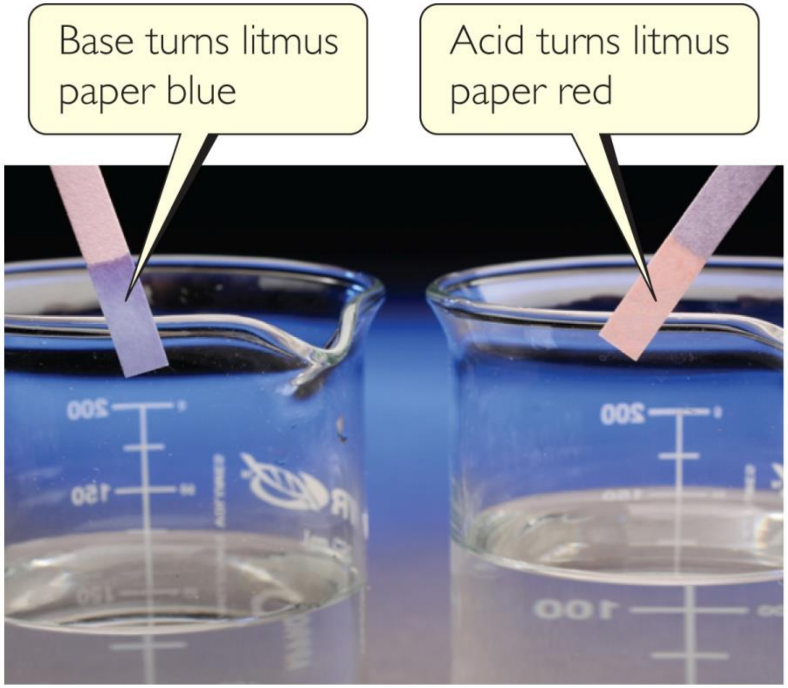
Acids



- The Swedish physicist and chemist S. A. Arrhenius defined acids as substances that increase the concentration of H^+ when dissolved in water.
- Both the Danish chemist J. N. Brønsted and the British chemist T. M. Lowry defined them as proton donors (质子供体).

Bases

- Arrhenius defined bases as substances that increase the concentration of OH^- when dissolved in water.
- Brønsted and Lowry defined them as proton acceptors (质子受体).



Strong or Weak?

- Strong acids completely dissociate in water; weak acids only partially dissociate.
- Strong bases dissociate to metal cations and hydroxide anions in water; weak bases only partially react to produce hydroxide anions.

Table 4.2 Common Strong Acids and Bases

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

Strong or Weak?

$$HA \underset{\text{solvent}}{\overset{pK_a}{\rightleftharpoons}} A^- + H^+$$

$$pK_a = -\log\left(\frac{[A^-][H^+]}{[HA]}\right)$$

*i*Bond键能数据库：http://ibond.nankai.edu.cn

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CHINA *i*BonD 2.0 internet Bond-energy Databank

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pK_a R-H $\xrightleftharpoons{\text{Het}}$ R^- + H^+ Enter

BDE R-R' $\xrightarrow{\text{Homo}}$ R· + R'· Enter

*i*BonD 2.0 Version was *Enriched!*

As known for its 1.0 version, the *i*BonD is a user-friendly internet-based databank of heterolytic (pK_a) and homolytic (BDE) bond dissociation energies, established by the bond energy team at Tsinghua University and Nankai University, China. Now, it is upgraded to the 2.0 version. The most noteworthy features of *i*BonD 2.0 are: 1) 7500 homolytic bond dissociation enthalpy (BDE) values for over 5,000 representative organic compounds with various kinds of chemical bonds are now made readily searchable online, and 2) the pK_a compilation is now substantially enriched to have more than 30,000 experimental equilibrium acidity data for about 20,000 compounds in various solvents. Thus, the *i*BonD 2.0 provides the heretofore most comprehensive bond energy collection and the most convenient approach to find the data with its powerful searching engine. Further updating of *i*BonD to compile the BDE values in solutions, the BDEs of metallic bonds, the energetics of some weak interactions (e.g. hydrogen bond, coordination bond) etc. will be done in our routine maintenances.

The *i*BonD is provided free of charge for non-profit making academic use only. Whenever applicable, the users of the *i*BonD are requested to cite this website in their publication/presentation as following: **Internet Bond-energy Databank (pK_a and BDE)--*i*BonD Home Page. http://ibond.nankai.edu.cn**. All rights are reserved by the *i*BonD team.

Feedbacks from users are highly valuable for improving the *i*BonD and will be most appreciated.

Contact information: Dr. Jin-Dong Yang: *jdyang@mail.tsinghua.edu.cn*

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At a glance: 41,000 pK_as | 7,600 BDEs

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pK_a : lower | upper

Solvent : All

Molecule editor

C N O S F Cl Br I P X FG

Similarity Search 0.5~1

Substructure search

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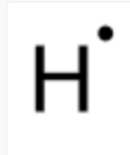
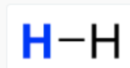
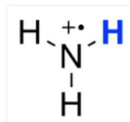
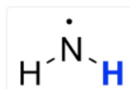
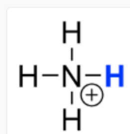
Compound Classification

- Inorganic acids
- Hydrocarbons
- Carboxylic acids
- Compounds with NH
- Aromatic heterocyclic compounds
- Compounds with -C(O), -C(O)NR and -C(C
- Compounds with -CN, -NC and -NO2
- Compounds with -S, -SO and -SO2
- Organic phosphoric derivatives
- Amino acid derivatives

Structure	Solvent	pK_a	Method	Ref.
	Gas	313.3	FT-ICR	92V
	H_2O	9.65	SM	74H2
	H_2O	31	Est.	86P
	Gas	179.5	TC	82N
	H_2O	6.7	SM	74H2
	H_2O	11.9	Est.	71S
	AA	3.1	PTM	30H
	Ac	13.7	PTM	08Z2
	AN	16.46	PTM	65C
	BmimNTf2	13.15	IOM	15M3
	BmpyNTf2	13.4	IOM	15M3
	D_2O	9.88	KM	67G
	D_2O	9.76	PTM	36S
	Diox 50%	8.89	PTM	55H3
	DMSO	10.5	IOM	88B
	EtOH	11.4	PTM	08Z2

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Search by

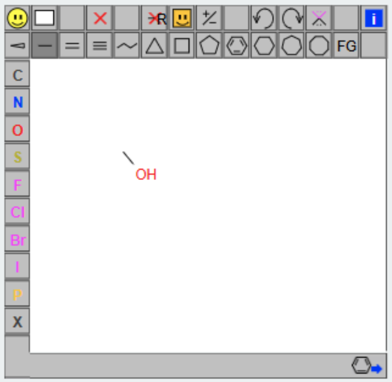
Name ▾ | e.g. cyanic acid

Filter by

pK_a : lower upper

Solvent : All

Molecule editor



◉ Similarity Search 0.5~1

○ Substructure search

Reset Search

Compound Classification

- Inorganic acids
- Hydrocarbons
- Carboxylic acids
- Compounds with NH
- Aromatic heterocyclic compounds
- Compounds with -C(O), -C(O)NR and -C(C
- Compounds with -CN, -NC and -NO2
- Compounds with -S, -SO and -SO2
- Organic phosphoric derivatives
- Amino acid derivatives

Structure	Solvent	pK_a	Method	Ref.
$HO{-}\dot{C}H_2$	H_2O	10.7		85S
CH_3OH Autoprotolysis	MeOH	16.92	SM	08C4
	MeOH	16.7	PTM	62C
$H_3C{-}OH$	DMSO	29	IOM	80O
	Gas	375.1	Therm.	90E
	Gas	374.9	TC	90E
	Gas	372	ICR	14H2
	Gas	374	FT-ICR	88T
	H_2O	15.7	SM	77H
	H_2O	15.49	PTM	87G2
	H_2O	15.54	CM	60B
	MeOH	18.3	SM	98C3
$H_3C{-}\overset{\oplus}{O}H_2$	AN	2.36	SM	68K1
	H_2O	-1.05	SM	70A
	H_2O	-2.2	RS	70A
	H_2O	-4.9	RS	70A
	H_2O	-1.98	NMR	73B4
	H_2O	-0.34	CM	70A

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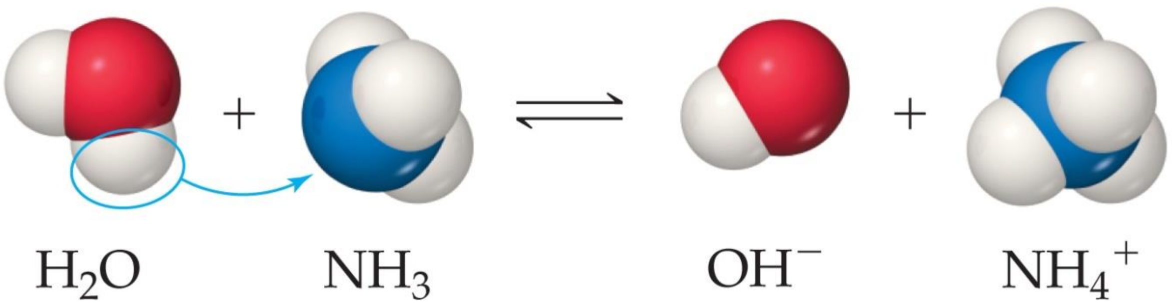
Acid-Base Reactions



- In an acid–base reaction, the acid (H_2O above) donates a proton (H^+) to the base (NH_3 above).
- Reactions between an acid and a base are called **neutralization reactions**.
- When the base is a metal hydroxide, water and a **salt** (an ionic compound) are produced.

Neutralization Reactions

When a strong acid (like HCl) reacts with a strong base (like NaOH), the net ionic equation is circled below:

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

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

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

Gas-Forming Reactions

- Some metathesis reactions do not give the product expected.
- When a carbonate (碳酸盐) or bicarbonate (碳酸氢盐) reacts with an acid, the products are a salt, carbon dioxide, and water.

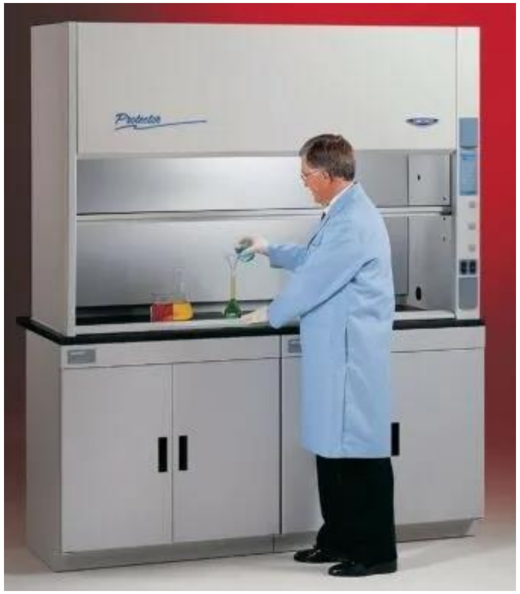
$$CaCO_3(s) + 2\ HCl(aq) \longrightarrow CaCl_2(aq) + CO_2(g) + H_2O(l)$$

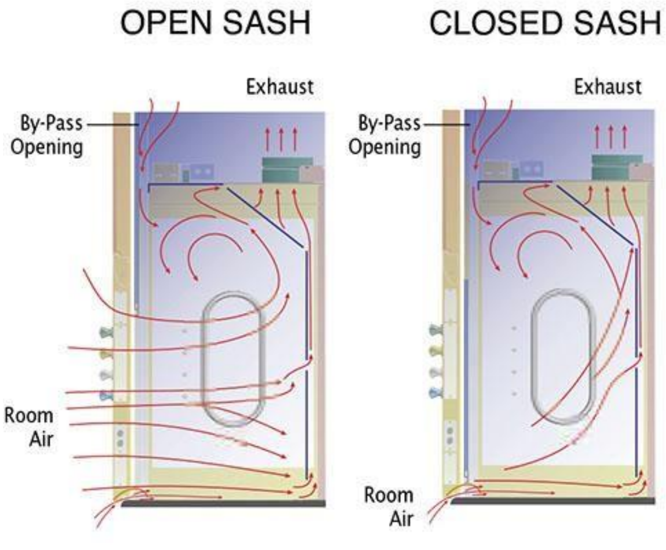
$$NaHCO_3(aq) + HBr(aq) \longrightarrow NaBr(aq) + CO_2(g) + H_2O(l)$$

Gas-Forming Reactions

This reaction gives the predicted product, but you had better carry it out in the hood—the gas produced has a foul odor!

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





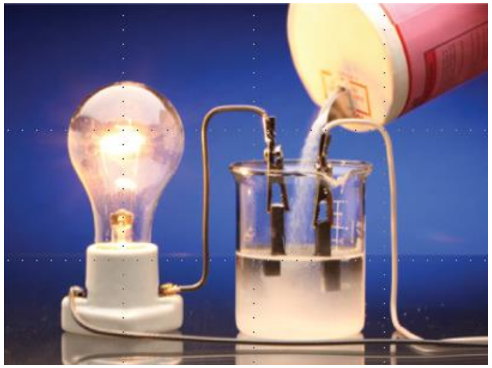
GIVE IT SOME THOUGHT?

Which ions, if any, are spectator ions in the reaction
$Ba(NO_3)_2$ *(aq)* + Na_2SO_4 *(aq)* $\longrightarrow$ $BaSO_4$ *(s)* + $2NaNO_3$ *(aq)* ?

A. Ba^{2+}(aq) and NO_3^-(aq)
B. NO_3^-(aq) and SO_4^{2-}(aq)
$\boxed{\text{C.}}$ Na^+(aq) and NO_3^-(aq)
D. No spectator ions are involved

GIVE IT SOME THOUGHT

Which solute will cause the lightbulb in Figure 4.2 to glow most brightly, CH_3OH, NaOH, or CH_3COOH?



A. $CH_3OH(aq)$

B. NaOH(aq)

C. $CH_3COOH(aq)$ 醋酸-acetic acid

D. Cannot determine from Figure 4.2

$$NaOH(aq) \longrightarrow Na^+(aq) + OH^-(aq)$$

$$CH3COOH(aq) \rightleftharpoons CH_3COO^-(aq) + H^+(aq)$$

GIVE IT SOME THOUGHT

What dissolved species are present in a solution of

a. KCN,

b. $NaClO_4$?

a.

A. $H_2O(l)$

B. $K^+(aq)$ and $H_2O(l)$

C. $CN^-(aq)$

D. $K^+(aq)$ and $CN^-(aq)$

b.

A. $H_2O(l)$

B. $Na^+(aq)$ and $H_2O(l)$

C. $ClO_4^-(aq)$

D. $Na^+(aq)$ and $ClO_4^-(aq)$

钠离子Na^+-sodium ion

钾离子K^+-potassium ion

高氯酸根离子ClO_4^- -perchlorate ion

氰离子CN^-- cyanide ion

GIVE IT SOME THOUGHT

By analogy to examples given in the text, predict what gas forms when $Na_2SO_3(s)$ reacts with $HCl(aq)$.

Sodium sulfite-亚硫酸钠

Sodium sulfide-硫化钠

Sodium sulfate-硫酸钠

A. $SO_2(g)$

B. $H_2(g)$

C. $CO_2(g)$

D. $H_2S(g)$

Hydrogen sulfide

sulfur dioxide-二氧化硫

Sulfite ion-亚硫酸根离子

Bisulfite-亚硫酸氢根离子 HSO3

Sulfate ion-硫酸根 SO42-

Sulfuric acid-硫酸

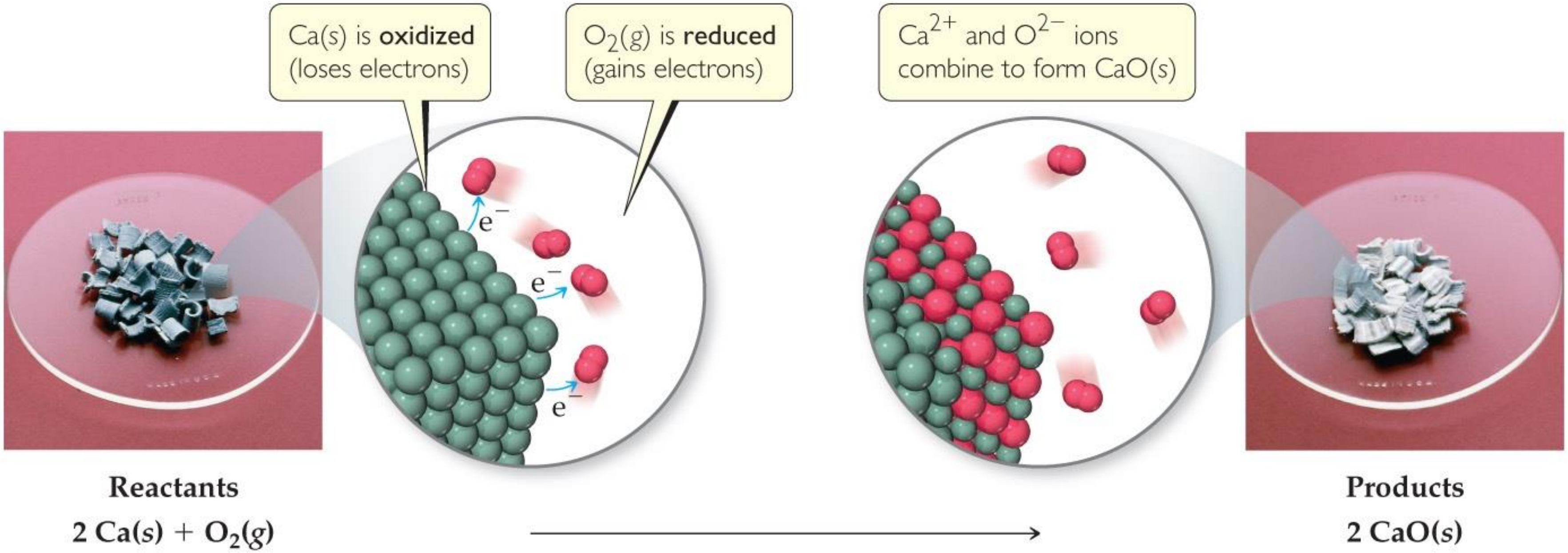
hydrosulfuric acid –氢硫酸 H2

Na2S2O3 硫代硫酸钠 sodium t

$$Na_2SO_3(aq) + 2HCl(aq) \longrightarrow SO_2(g) + NaCl(aq) + H_2O$$

$$SO_3^{2-}(aq) + H^+(aq) \longrightarrow SO_2(g) + H_2O$$

Oxidation-Reduction Reactions



- Loss of electrons is **oxidation**.
- Gain of electrons is **reduction**.
- One cannot occur without the other.
- The reactions are often called **redox reactions**.

Oxidation Numbers 氧化数

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

Rules to Assign Oxidation Numbers

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

Fe^{2+} Fe^{3+}

Mn^{2+} MnO_4^-

Rules to Assign Oxidation Numbers

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

Rules to Assign Oxidation Numbers

- Fluorine always has an oxidation number of −1.
- The other halogens have an oxidation number of −1 when they are negative; they can have positive oxidation numbers, most notably in oxyanions.

Rules to Assign Oxidation Numbers

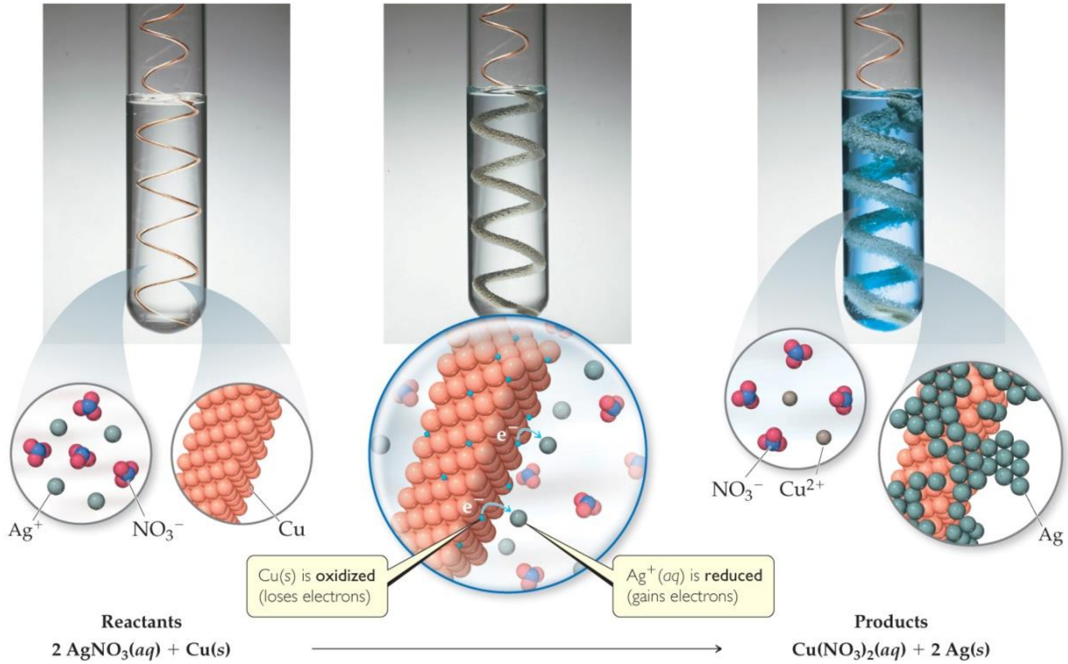
- **The sum of the oxidation numbers in a neutral compound is zero**.
- The sum of the oxidation numbers in a polyatomic ion is the charge on the ion.

e.g. MnO_4^-

Displacement Reactions 置换反应

In **displacement reactions**, **ions oxidize an element**.

In this reaction, silver ions oxidize copper metal:



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

The reverse reaction does NOT occur. Why not?

Activity Series

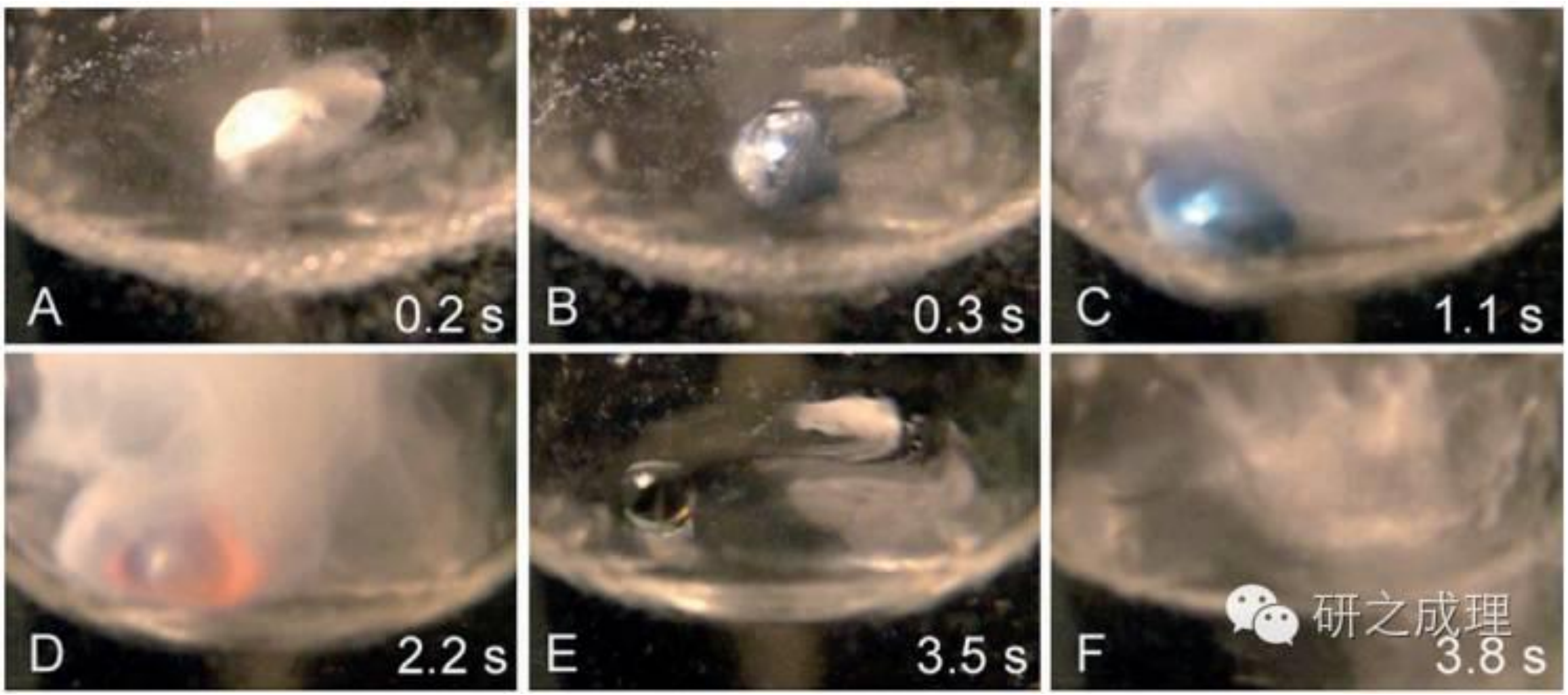
Table 4.5 Activity Series of Metals in Aqueous Solution

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

- Elements higher on the activity series are more reactive.
- They are more likely to exist as ions.

Metal/Acid Displacement Reactions

- The elements above hydrogen will react with acids to produce hydrogen gas.
- The metal is oxidized to a cation.



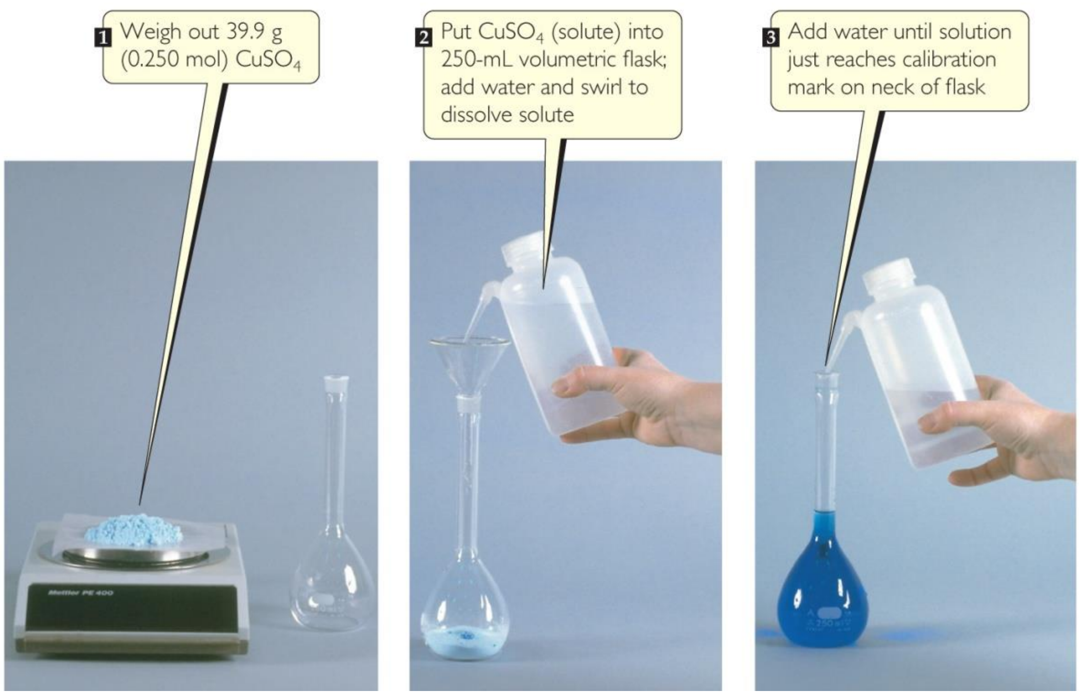
Molarity 摩尔浓度

- The quantity of solute in a solution can matter to a chemist.
- We call the amount dissolved its **concentration**.
- **Molarity** is one way to measure the concentration of a solution:

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

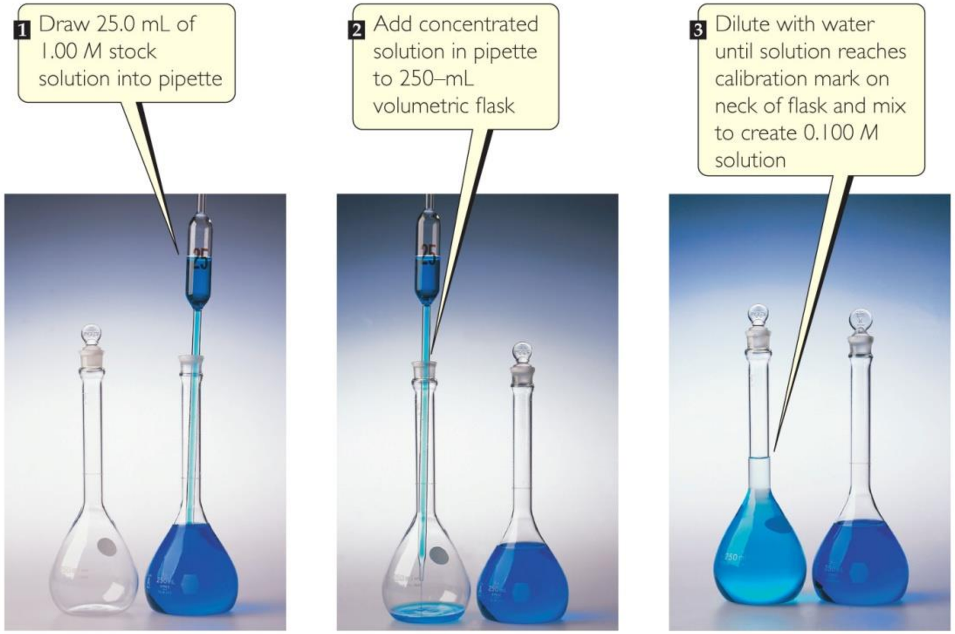
Mixing a Solution

- To create a solution of a known molarity, weigh out a known mass (and, therefore, number of moles) of the solute.
- Then add solute to a volumetric flask (容量瓶), and add solvent to the line on the neck of the flask.



Dilution 稀释

- One can also dilute a more concentrated solution by
  - using a pipet (移液管) to deliver a volume of the solution to a new volumetric flask, and
  - adding solvent to the line on the neck of the new flask.



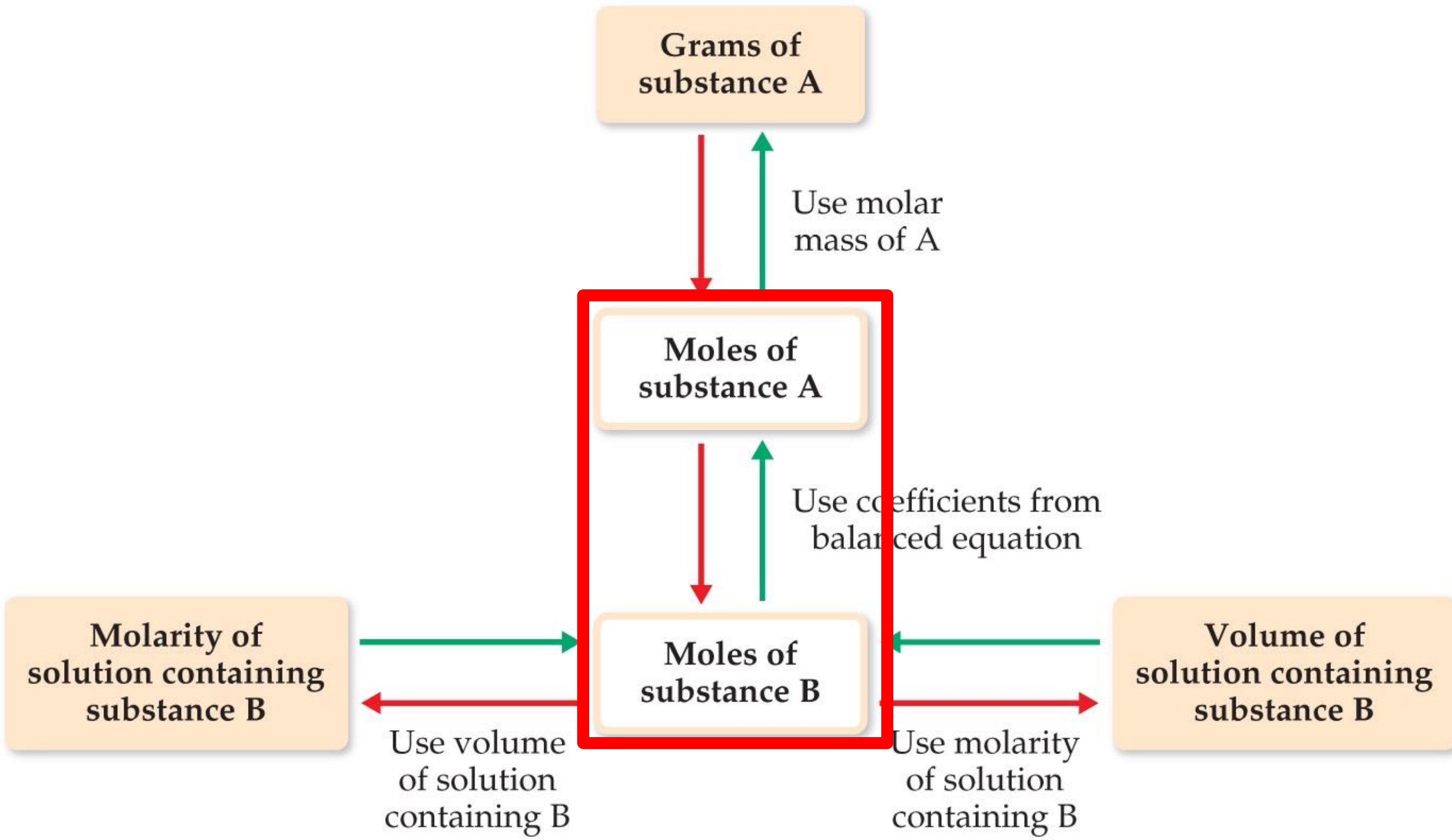
Dilution

The molarity of the new solution can be determined from the equation

$$M_c \times V_c = M_d \times V_d,$$

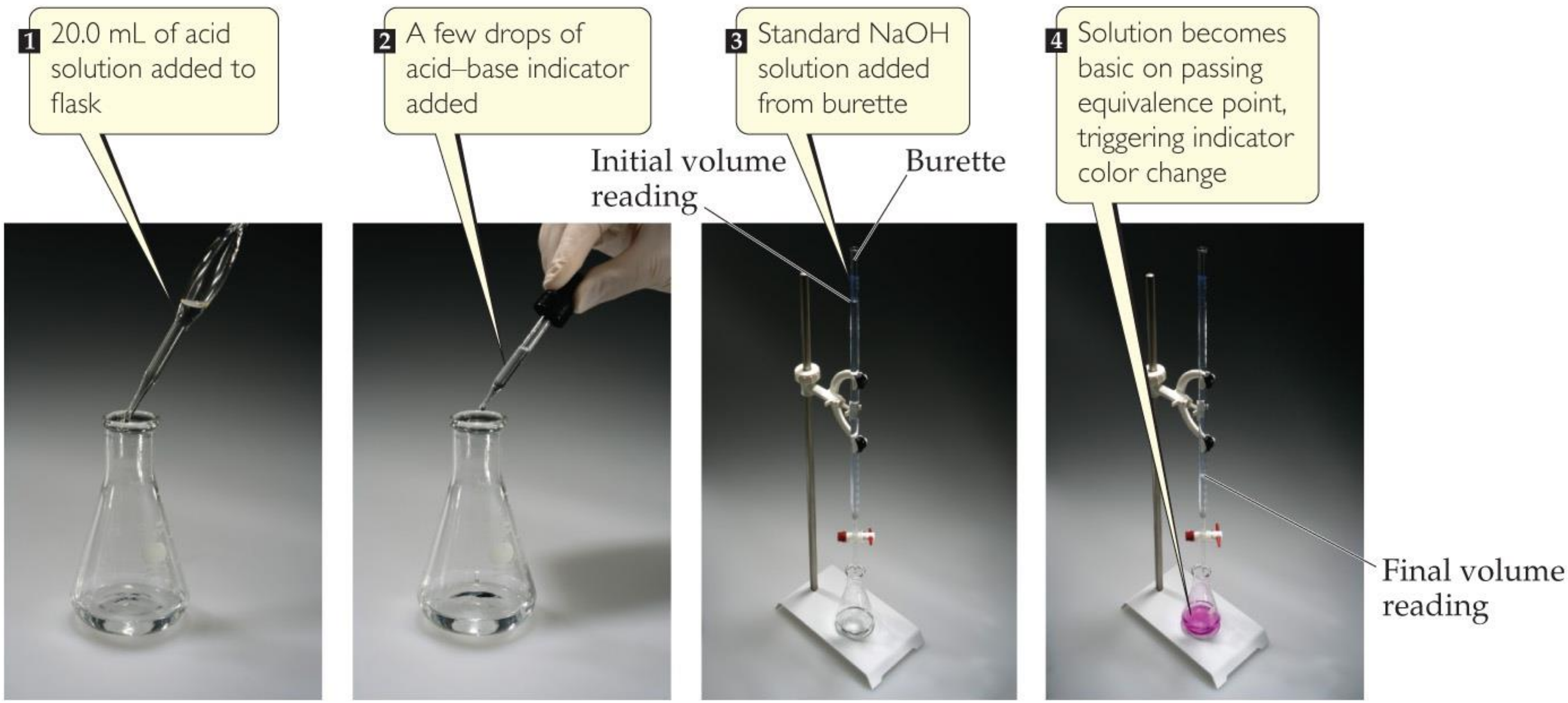
where M_c and M_d are the molarity of the concentrated and dilute solutions, respectively, and V_c and V_d are the volumes of the two solutions.

Using Molarities in Stoichiometric Calculations

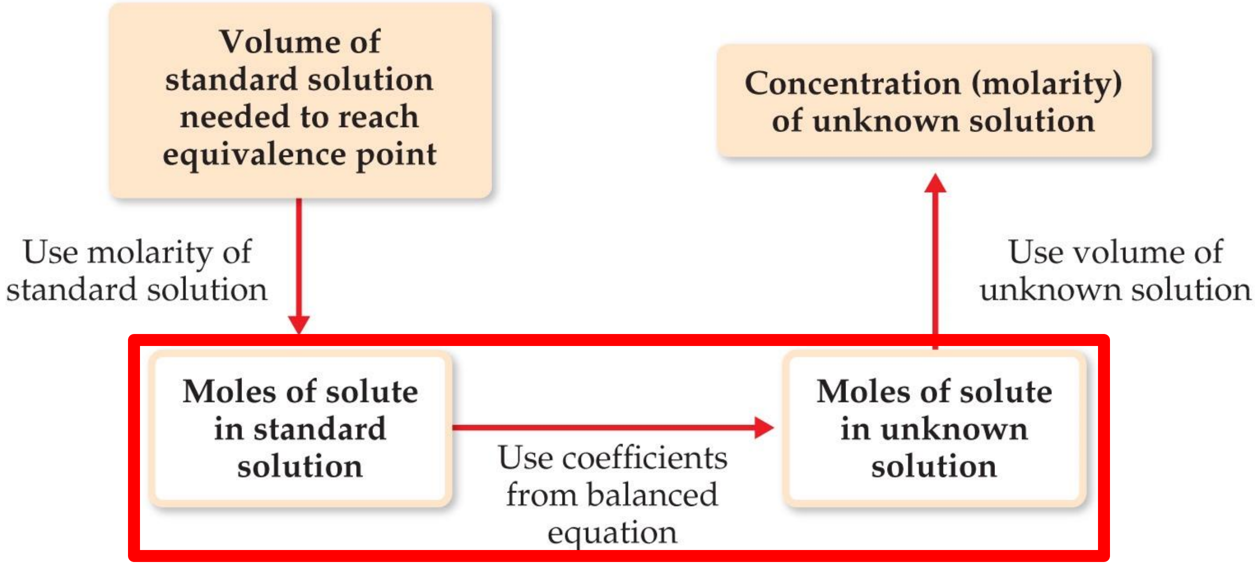


Titration 滴定

A **titration** is an analytical technique in which one can calculate the concentration of a solute in a solution.

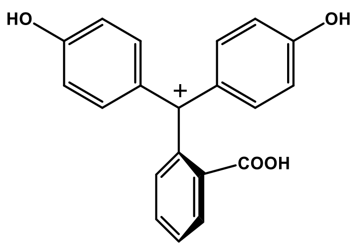
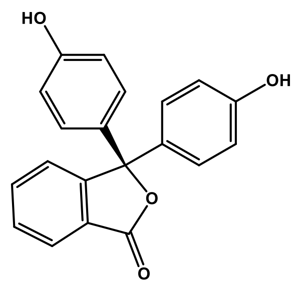
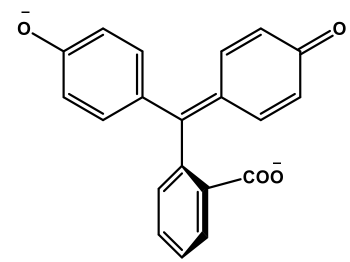
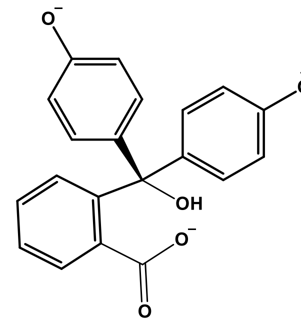
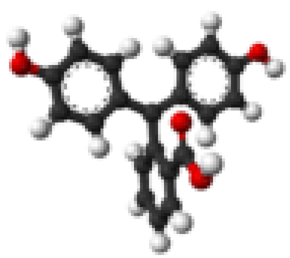
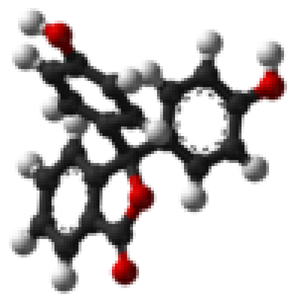
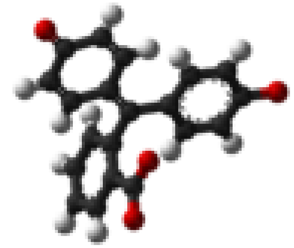
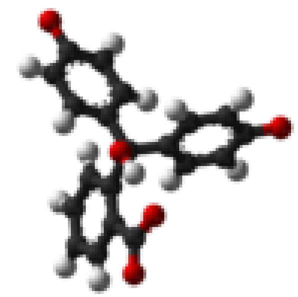


Titration



- A solution of known concentration, called a **standard solution**, is used to determine the unknown concentration of another solution.
- The reaction is complete at the **equivalence point**.

➢ Acid-Base Indicator Phenolphthalein (In, 酚酞)

Species	In^+	H_2In	In^{2-}	$In(OH)^{3-}$
Structure				
Model				
pH	<0	0–8.2	8.2–12.0	>12.0
Conditions	strongly acidic	acidic or neutral	basic	strongly basic
Color	orange	colorless	pink	colorless
Image				

A homogeneous mixture of two or more components is referred to as

a. a solute.

b. a solution.

c. an electrolyte.

d. a mess.

The solvent in a sample of soda pop is

a. sugar.
b. carbon dioxide.
c. water.
d. air.

The gaseous solute in a sample of soda pop is

a. sugar.
b. carbon dioxide.
c. water.
d. air.

Gatorade（佳得乐）conducts electricity because it contains

a. water.
b. sugar.
c. air.
d. electrolytes.

When $Fe(NO_3)_2$ dissolves in water, the particles in solution are

a. Fe^{+} and $(NO_3)_2^{-}$.
$\boxed{b.}$ Fe^{2+} and 2 NO_3^{-}.
c. Fe and 2 NO_3.
d. Fe and N_2 and 3 O_2.

Which compound below is NOT soluble in water?

a. NaBr
b. KNO_3
c. $MgSO_4$
d. ZnS

$Pb(NO_3)_2 + 2\ KI \rightarrow PbI_2 + 2\ KNO_3$

The physical evidence that the above reaction occurs is

a. an explosion.

b. formation of a gas.

c. the solution boils.

d. formation of a precipitate.

When an acid reacts with a base, the result is

a. cancellation.
b. elimination.
c. neutralization.
d. adduct formation.

Which compound below is NOT a strong acid?

a. CH_3CO_2H
b. H_2SO_4
c. HNO_3
d. HBr

When an atom undergoes oxidation, it ________ electrons.

a. gains
b. $\boxed{\text{b.}}$ loses
c. retains
d. balances

When an atom undergoes reduction, it _______ electrons.

a. gains
b. loses
c. retains
d. balances

$Al + H^+ \rightarrow Al^{3+} + H_2$

When the oxidation-reduction reaction above is correctly balanced, the coefficients are

a. 1, 2 → 1, 1.

b. 1, 3 → 1, 2.

c. 2, 3 → 2, 3.

$\boxed{\text{d.}}$ 2, 6 → 2, 3.

250.0 mL of 0.100 M $AgNO_3$ solution contains ______ grams of silver nitrate.

M-mol/L

a. 4.25

b. 8.50

c. 17.0

d. 34.0

The Periodic Table of the Elements

1 **H** Hydrogen 1.00794																	2 **He** Helium 4.003
3 **Li** Lithium 6.941	4 **Be** Beryllium 9.012182											5 **B** Boron 10.811	6 **C** Carbon 12.0107	7 **N** Nitrogen 14.00674	8 **O** Oxygen 15.9994	9 **F** Fluorine 18.9984032	10 **Ne** Neon 20.1797
11 **Na** Sodium 22.989770	12 **Mg** Magnesium 24.3050											13 **Al** Aluminum 26.981538	14 **Si** Silicon 28.0855	15 **P** Phosphorus 30.973761	16 **S** Sulfur 32.066	17 **Cl** Chlorine 35.4527	18 **Ar** Argon 39.948
19 **K** Potassium 39.0983	20 **Ca** Calcium 40.078	21 **Sc** Scandium 44.955910	22 **Ti** Titanium 47.867	23 **V** Vanadium 50.9415	24 **Cr** Chromium 51.9961	25 **Mn** Manganese 54.938049	26 **Fe** Iron 55.845	27 **Co** Cobalt 58.933200	28 **Ni** Nickel 58.6934	29 **Cu** Copper 63.546	30 **Zn** Zinc 65.39	31 **Ga** Gallium 69.723	32 **Ge** Germanium 72.61	33 **As** Arsenic 74.92160	34 **Se** Selenium 78.96	35 **Br** Bromine 79.904	36 **Kr** Krypton 83.80
37 **Rb** Rubidium 85.4678	38 **Sr** Strontium 87.62	39 **Y** Yttrium 88.90585	40 **Zr** Zirconium 91.224	41 **Nb** Niobium 92.90638	42 **Mo** Molybdenum 95.94	43 **Tc** Technetium (98)	44 **Ru** Ruthenium 101.07	45 **Rh** Rhodium 102.90550	46 **Pd** Palladium 106.42	47 **Ag** Silver 107.8682	48 **Cd** Cadmium 112.411	49 **In** Indium 114.818	50 **Sn** Tin 118.710	51 **Sb** Antimony 121.760	52 **Te** Tellurium 127.60	53 **I** Iodine 126.90447	54 **Xe** Xenon 131.29
55 **Cs** Cesium 132.90545	56 **Ba** Barium 137.327	57 **La** Lanthanum 138.9055	72 **Hf** Hafnium 178.49	73 **Ta** Tantalum 180.9479	74 **W** Tungsten 183.84	75 **Re** Rhenium 186.207	76 **Os** Osmium 190.23	77 **Ir** Iridium 192.217	78 **Pt** Platinum 195.078	79 **Au** Gold 196.96655	80 **Hg** Mercury 200.59	81 **Tl** Thallium 204.3833	82 **Pb** Lead 207.2	83 **Bi** Bismuth 208.98038	84 **Po** Polonium (209)	85 **At** Astatine (210)	86 **Rn** Radon (222)
87 **Fr** Francium (223)	88 **Ra** Radium (226)	89 **Ac** Actinium (227)	104 **Rf** Rutherfordium (261)	105 **Db** Dubnium (262)	106 **Sg** Seaborgium (263)	107 **Bh** Bohrium (262)	108 **Hs** Hassium (265)	109 **Mt** Meitnerium (266)	110 (269)	111 (272)	112 (277)	113	114				

				58 **Ce** Cerium 140.116	59 **Pr** Praseodymium 140.90765	60 **Nd** Neodymium 144.24	61 **Pm** Promethium (145)	62 **Sm** Samarium 150.36	63 **Eu** Europium 151.964	64 **Gd** Gadolinium 157.25	65 **Tb** Terbium 158.92534	66 **Dy** Dysprosium 162.50	67 **Ho** Holmium 164.93032	68 **Er** Erbium 167.26	69 **Tm** Thulium 168.93421	70 **Yb** Ytterbium 173.04	71 **Lu** Lutetium 174.967
				90 **Th** Thorium 232.0381	91 **Pa** Protactinium 231.03588	92 **U** Uranium 238.0289	93 **Np** Neptunium (237)	94 **Pu** Plutonium (244)	95 **Am** Americium (243)	96 **Cm** Curium (247)	97 **Bk** Berkelium (247)	98 **Cf** Californium (251)	99 **Es** Einsteinium (252)	100 **Fm** Fermium (257)	101 **Md** Mendelevium (258)	102 **No** Nobelium (259)	103 **Lr** Lawrencium (262)

1995 IUPAC masses and Approved Names from http://www.chem.qmw.ac.uk/iupac/AtWt/
masses for 107-111 from C&EN, March 13, 1995, p. 35
112 from http://www.gsi.de/z112e.html

To make 250.0 mL of 0.500 M KI solution, ______ mL of 6.00 M KI must be used.

a. 20.8
b. 41.7
c. 500.0
d. 3000.0

M-mol/L

HX + NaOH → NaX + H_2O
229 mg of HX was titrated using 29.70 mL of 0.0965 M NaOH. What is element X?

a. F
b. Cl
c. Br
d. I

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