普通化學
科学的范畴

自然科学 → 数学

物理学 → 生物科学

天文学 → 动物学

地球科学 (研究物质以及能量)

有机化学、无机化学

物理化学、生物化学

物理、化学

跨领域：化学物理

分子化学，分子生物学

生物学、微生物学

遗传学、遗传学

生理学

生物科学

植物学

微生物学

动物学
Lecture I: 化学的范畴

What is chemistry?

↓

The science that tries to understand:

1) The properties of substances
   物質的性質

2) The changes that substances undergo
   物質的變化

Want to understand materials including:

A. Natural substances: 天然物質
   e.g. mineral, air, water, salt ...

B. Chemicals found in living creatures: 生物體內化合物
   e.g. DNA, protein, carbohydrate, ..... 

C. New compounds created by chemists: 新化合物
   e.g. polymer, nylon, ...
Figure 3.2.1.3
Various parts of the scientific method
### Chap 1.3 - Measurements

#### English system

#### Metric system

1960 A.D.

<table>
<thead>
<tr>
<th>International System (S.I. units)</th>
<th>S.I System</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physical Quantity</td>
<td>Name of units</td>
</tr>
<tr>
<td>Mass</td>
<td>Kilogram</td>
</tr>
<tr>
<td>Length</td>
<td>Meter</td>
</tr>
<tr>
<td>Time</td>
<td>Second</td>
</tr>
<tr>
<td>Temperature</td>
<td>Kelvin</td>
</tr>
<tr>
<td>Electric current</td>
<td>Ampere</td>
</tr>
<tr>
<td>Amount of substance</td>
<td>Mole</td>
</tr>
</tbody>
</table>

#### Table 1.2 - The Prefixes Used in the S.I System

<table>
<thead>
<tr>
<th>Prefix</th>
<th>Exponent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exa</td>
<td>$10^{18}$</td>
</tr>
<tr>
<td>Peta</td>
<td>$10^{15}$</td>
</tr>
<tr>
<td>Tera</td>
<td>$10^{12}$</td>
</tr>
<tr>
<td>Giga</td>
<td>$10^{9}$</td>
</tr>
<tr>
<td>Mega</td>
<td>$10^{6}$</td>
</tr>
<tr>
<td>Kilo</td>
<td>$10^{3}$</td>
</tr>
<tr>
<td>Hecto</td>
<td>$10^{2}$</td>
</tr>
<tr>
<td>Deca</td>
<td>$10^{1}$</td>
</tr>
<tr>
<td>Deci</td>
<td>$10^{-1}$</td>
</tr>
<tr>
<td>Centi</td>
<td>$10^{-2}$</td>
</tr>
<tr>
<td>Milli</td>
<td>$10^{-3}$</td>
</tr>
<tr>
<td>Micro</td>
<td>$10^{-6}$</td>
</tr>
<tr>
<td>Nano</td>
<td>$10^{-9}$</td>
</tr>
<tr>
<td>Pico</td>
<td>$10^{-12}$</td>
</tr>
<tr>
<td>Femto</td>
<td>$10^{-15}$</td>
</tr>
<tr>
<td>Atto</td>
<td>$10^{-18}$</td>
</tr>
</tbody>
</table>
100-mL graduated cylinder

25-mL pipet

50-mL buret

250-mL volumetric flask

Calibration mark indicates 25-mL volume

Valve (stopcock) controls the liquid flow

Calibration mark indicates 250-mL volume
Measuring liquid volume with a buret

Buret

mL

0

10

20

30

40

50

22.2 mL

"meniscus"
bottom of the liquid curve
The difference between precision and accuracy

1. Not precise, not accurate

2. Precision but no accuracy

3. Accuracy & precision
1.5 Significant Figures

1. Nonzero integers 非零整数

2. Three classes of zeros
   (a) Leading zeros  首位零
      e.g. 0.0025
          不算
   (b) Captive zeros  在非零数字之间
      e.g. 1.008
          算
   (c) Trailing zeros 尾巴的零
      e.g. 100  1位
            100.  3位
            1.00  3位

+ 从最不准确的位数为准 e.g. \[ \frac{12.11}{18.0} = 0.67 \]

\[ \text{corrected} = 0.67 \]

\[ 30.1 \]

\[ \text{s.f.} \]

\[ \text{小数点第一位} \]
Temperature

Fahrenheit

Boiling point of water

212°F

180 Fahrenheit degrees

Freezing point of water

32°F

-40°F

Celsius

100°C

100 Celsius degrees

0°C

-40°C

Kelvin

373.15 K

100 kelvins

273.15 K

233.15 K

\[ T_F = T_C \times \frac{9}{5} + 32°F \]

\[ T_K = T_C + 273.15 \]
Distillation apparatus

蒸餾系統
Figure 1.13
The organization of matter

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Chapter 2 atoms, Molecules, and Ions

2.1 The Early History of Chemistry

A. 古代 → ~400 B.C.
   (a) Before 1000 B.C.
   利用礦物製造武器及裝飾品
   防腐液体 → 製造木乃伊
   (b) 400 B.C. 希臘人
   四大元素 (elements)
   Air, Fire, Water, and Earth
   物質是否是連續的?
B. 400 B.C. ~ 1600 A.D. (至今2000年左右)
   鎮金術
   Gold can be turned from Other Metals
C. Boyle 時代 (1627 - 1691 AD)
   "定量" 化學家
The Skeptical Chymist (in 1661)
Pressures and Volume of Gases

Element Concepts

Boyle Times Following:

A. Antoine Lavoisier

(a) Law of Conservation of Mass
"Mass is neither created nor destroyed"

(b) Combustion Utilizing O₂

B. Joseph Proust

Law of Definite Proportion
"A given compound always contains exactly the same proportion of elements by mass."
E. Dalton

law of multiple proportions (倍比定理)
"When two elements form a series of compounds, the ratios of the masses of the second element that combine w/ 1 gram of the first element can always be reduced to small whole numbers."
Nitrogen and Oxygen compounds

Compound A

\[
\frac{A}{B} = \frac{1.750}{0.875} = \frac{2}{1}
\]

\[
\frac{B}{C} = \frac{0.8750}{0.4375} = \frac{2}{1}
\]

\[
\frac{A}{C} = \frac{1.750}{0.4375} = \frac{4}{1}
\]

Nitrogen mass that combines w/ 1 g oxygen: 1.750 g

B: 0.8750 g

C: 0.4375 g

Meaning?
Dalton's Atomic Theory

"A New System of Chemical Philosophy"

1. Each element is made up of tiny particles called atoms.

2. The atoms of a given element are identical; the atoms of different elements are different in some fundamental way or ways.

3. Chemical compounds are formed when atoms combine with each other. A given compound always has the same relative numbers and types of atoms.

4. Chemical reactions involve reorganization of atoms - changes in the way that they are bound together. The atoms themselves are not changed in a chemical reaction.
2.4 Early Experiments to Characterize the Atom

The electron

Thomson's experiment

cathode-ray tubes 陰極射線管

FIGURE 2.7
A cathode-ray tube. The fast-moving electrons excite the gas in the tube, causing a glow between the electrodes. The green color in the photo is due to the response of the screen (coated with zinc sulfide) to the electron beam.

cathode ray: because it emanated from the negative electrode, or cathode

1. The ray was a stream of negatively charged particles, now called “electrons"

\( e/m = -1.76 \times 10^{-8} \ \text{C/g} \)

\( C = \text{coulombs} \)
FIGURE 2.9
The plum pudding model of the atom.
Millikan's experiment

Figure 2.10
Diagram of Millikan apparatus

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Millikan's experiment

\text{mass of electron} = 9.11 \times 10^{-31} \text{ kg}

F = -qE + mg = 0

\text{油滴运动}
- Source of $\alpha$ particles
- Beam of $\alpha$ particles
- Screen to detect scattered $\alpha$ particles
- Thin metal foil
- Some $\alpha$ particles are scattered
- Most particles pass straight through foil
Chapter 2.4

Rutherford's Experiment

1. Most of the α particles pass directly through the foil because the atom is mostly open space.

2. The deflected α particles are those which had a "close encounter" with the massive positive center of the atom.

3. The few reflected α particles are those which made a "direct hit" on the much more massive positive center, 
   a dense center of positive charge, nuclear atom (nucleus).
2.5 The Modern View of Atomic Structure: An Introduction

<table>
<thead>
<tr>
<th>Particle</th>
<th>Mass</th>
<th>Charge</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electron</td>
<td>$9.11 \times 10^{-31} \text{ kg}$</td>
<td>1-</td>
</tr>
<tr>
<td>Proton</td>
<td>$1.67 \times 10^{-27} \text{ kg}$</td>
<td>1+</td>
</tr>
<tr>
<td>Neutron</td>
<td>$1.67 \times 10^{-27} \text{ kg}$</td>
<td>0</td>
</tr>
</tbody>
</table>

**FIGURE 2.14**
A nuclear atom viewed in cross section. Note that this drawing is not to scale.
mass #

→ A

→ Z

Atomic #

→ element symbol

Ex:

\[ _{11}^{23} \text{Na} \]

# of electron = 11

# of proton = 11

# of neutron = 23 - 11 = 12
2.6 Molecules and Ions

The forces that hold atoms together in compounds — chemical bonds

Covalent bonds: sharing electrons
  e.g. H₂ A (Ψ₁ + Ψ₂)

Ionic bonds: attraction between oppositely charged ions
  e.g. NaCl

Fig. 2.16

Spacing — filling models

Fig. 2.17 Ball-and-stick

Fig. 2.18
Figure 2.21
The periodic table

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2.8 Nomenclature

I. Binary Ionic Compounds (Type I)

1. Cation → first
   anion → second

2. Cation → from the name of the element
3. Anion → take the root of the name of the element and add -ide

Ex: NaCl  element names: sodium chlorine

sodium chloride

MgCl₂  element names: magnesium chlorine

magnesium chloride

* Type I Cations: 通常只有一种电荷

Table 2.3
See Fig. 2.22
FIGURE 2.22
The common cations and anions.

Common Type I cations  Common Type II cations  Common monatomic anions
Figure 2.23
Flowchart for naming binary compounds

- Binary compound? Yes
  - Metal present? No
    - Type III:
      Use prefixes.
  - Metal present? Yes
    - Does the metal form more than one cation? No
      - Type I:
        Use the element name for the cation.
    - Does the metal form more than one cation? Yes
      - Type II:
        Determine the charge of the cation;
        use a Roman numeral after the element name for the cation.
II. Binary Ionic Compounds (Type II)

* Type II Cations: 通常不带一种电荷
  Ex. Fe^{3+} & Fe^{2+}

See Fig. 2.22 & Table 2.4

1. Cation → first
   Anion → second

*2. Cation → from the name of the element
   But, adding the charge of the cation
   (using Roman numeral !)

  Ex. Fe^{3+}  Iron (III)
   Fe^{2+}  Iron (II)

3. Anion → take the element name's root
   and add -ide

  Ex. CuCl : element names: copper

  Solution: Cu^{+}Cl^{-}

  Copper (II) chloride

See page 61. 流程图 for Type II 的分别
Or

cation w/ the higher charge
→ -ic
w/ the lower charge
→ -ous

Ex. FeCl₃ element names: iron chloride
FeCl₂

Fe³⁺Cl₃: Ferric chloride
Fe²⁺Cl₂: Ferrous chloride

例题: 2-3 (page 63) Type I
2-4 (page 63) Type II
2-5 (page 64)

C₆₀ (page 65) Buckminsterfullerene
60个C (位于顶点) 组成 32个面球体
20个六面体 12个五面体 更多
Binary Compounds (Type III; Covalent — contain two Non-metals)

1. First element in the formula → first use the full element name.

2. Second element → name it as it were anion.

3. Prefixes are added to denote (Fred)
   the numbers of atoms present.
   1. mono-
   2. di-
   3. tri-
   4. tetra-
   5. penta-

4. Prefixes → never used for naming “mono” the first element.

Ex.: N₂O → di-nitrogen monoxide
     NO → nitrogen monoxide
     N₂O₂ → nitrogen dioxide
     N₂O₃ → di-nitrogen trioxide
     N₂O₂
### TABLE 2.3 Common Monatomic Cations and Anions

<table>
<thead>
<tr>
<th>Cation</th>
<th>Name</th>
<th>Anion</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>H⁺</td>
<td>Hydrogen</td>
<td>H⁻</td>
<td>Hydride</td>
</tr>
<tr>
<td>Li⁺</td>
<td>Lithium</td>
<td>F⁻</td>
<td>Fluoride</td>
</tr>
<tr>
<td>Na⁺</td>
<td>Sodium</td>
<td>Cl⁻</td>
<td>Chloride</td>
</tr>
<tr>
<td>K⁺</td>
<td>Potassium</td>
<td>Br⁻</td>
<td>Bromide</td>
</tr>
<tr>
<td>Cs⁺</td>
<td>Cesium</td>
<td>I⁻</td>
<td>Iodide</td>
</tr>
<tr>
<td>Ba²⁺</td>
<td>Beryllium</td>
<td>O²⁻</td>
<td>Oxide</td>
</tr>
<tr>
<td>Mg²⁺</td>
<td>Magnesium</td>
<td>S²⁻</td>
<td>Sulphide</td>
</tr>
<tr>
<td>Ca²⁺</td>
<td>Calcium</td>
<td>N³⁻</td>
<td>Nitride</td>
</tr>
<tr>
<td>Ba²⁺</td>
<td>Barium</td>
<td>P³⁻</td>
<td>Phosphide</td>
</tr>
<tr>
<td>Al³⁺</td>
<td>Aluminium</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ag⁺</td>
<td>Silver</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### TABLE 2.4 Common Type II Cations

<table>
<thead>
<tr>
<th>Ion</th>
<th>Systematic Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fe³⁺</td>
<td>Iron(III)</td>
</tr>
<tr>
<td>Fe²⁺</td>
<td>Iron(II)</td>
</tr>
<tr>
<td>Cu²⁺</td>
<td>Copper(II)</td>
</tr>
<tr>
<td>Cu⁺</td>
<td>Copper(I)</td>
</tr>
<tr>
<td>Co³⁺</td>
<td>Cobalt(III)</td>
</tr>
<tr>
<td>Co²⁺</td>
<td>Cobalt(II)</td>
</tr>
<tr>
<td>Sn³⁺</td>
<td>Tin(IV)</td>
</tr>
<tr>
<td>Sn²⁺</td>
<td>Tin(II)</td>
</tr>
<tr>
<td>Pb²⁺</td>
<td>Lead(IV)</td>
</tr>
<tr>
<td>Pb⁺</td>
<td>Lead(II)</td>
</tr>
<tr>
<td>Hg²⁺</td>
<td>Mercury(II)</td>
</tr>
<tr>
<td>Hg₂⁺</td>
<td>Mercury(I)</td>
</tr>
<tr>
<td>Ag⁺</td>
<td>Silver†</td>
</tr>
<tr>
<td>Zn²⁺</td>
<td>Zinc†</td>
</tr>
<tr>
<td>Cd²⁺</td>
<td>Cadmium†</td>
</tr>
</tbody>
</table>

*Note that mercury(I) ions always occur bound together to form Hg₂⁺ ions.
†Although these are transition metals, they form only one type of ion, and a Roman numeral is not used.
Polyatomic Ions Compounds

1. separate polyatomic ions w/ opposite charges

Ex. \( \text{NH}_4\text{OH} \) contains \( \text{NH}_4^+ \) and \( \text{OH}^- \)

2. polyatomic ions

→ must be memorized!!

See Table 2.5

Ex. a \( \text{NH}_4\text{OH} \)

\( \text{NH}_4^+ \text{ OH}^- \)

Ammonium Hydroxide

b \( \text{KClO}_4 \)

\( \text{K}^+ \text{ ClO}_4^- \)

Potassium Perchlorate

Ex. 2.6 (page 67)
Figure 2.25
Flowchart for naming acids

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<table>
<thead>
<tr>
<th>Ion</th>
<th>Name</th>
<th>Ion</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\text{Hg}_2^{2+}$</td>
<td>Mercury(I)</td>
<td>NCS$^-$</td>
<td>Thiocyanate</td>
</tr>
<tr>
<td>$\text{NH}_4^+$</td>
<td>Ammonium</td>
<td>CO$_3^{2-}$</td>
<td>Carbonate</td>
</tr>
<tr>
<td>$\text{NO}_2^-$</td>
<td>Nitrite</td>
<td>HCO$_3^-$</td>
<td>Hydrogen carbonate</td>
</tr>
<tr>
<td>$\text{NO}_3^-$</td>
<td>Nitrate</td>
<td></td>
<td>(bicarbonate is a widely used common name)</td>
</tr>
<tr>
<td>$\text{SO}_3^{2-}$</td>
<td>Sulfite</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\text{SO}_4^{2-}$</td>
<td>Sulfate</td>
<td>ClO$^-$</td>
<td>Hypochlorite</td>
</tr>
<tr>
<td>$\text{HSO}_4^-$</td>
<td>Hydrogen sulfate</td>
<td>ClO$_2^-$</td>
<td>Chlorite</td>
</tr>
<tr>
<td></td>
<td>(bisulfate is a widely used common name)</td>
<td>ClO$_3^-$</td>
<td>Chlorate</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ClO$_4^-$</td>
<td>Perchlorate</td>
</tr>
<tr>
<td>$\text{OH}^-$</td>
<td>Hydroxide</td>
<td>$\text{C}_2\text{H}_3\text{O}_2^-$</td>
<td>Acetate</td>
</tr>
<tr>
<td>$\text{CN}^-$</td>
<td>Cyanide</td>
<td>MnO$_4^-$</td>
<td>Permanganate</td>
</tr>
<tr>
<td>$\text{PO}_4^{3-}$</td>
<td>Phosphate</td>
<td>Cr$_2$O$_7^{2-}$</td>
<td>Dichromate</td>
</tr>
<tr>
<td>$\text{HPO}_4^{2-}$</td>
<td>Hydrogen phosphate</td>
<td>CrO$_4^{2-}$</td>
<td>Chromate</td>
</tr>
<tr>
<td>$\text{H}_2\text{PO}_4^-$</td>
<td>Dihydrogen phosphat</td>
<td>O$_2^{2-}$</td>
<td>Peroxide</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$\text{C}_2\text{O}_4^{2-}$</td>
<td>Oxalate</td>
</tr>
</tbody>
</table>
### Table 2.7 Names of Acids* That Do Not Contain Oxygen

<table>
<thead>
<tr>
<th>Acid</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>HF</td>
<td>Hydrofluoric acid</td>
</tr>
<tr>
<td>HCl</td>
<td>Hydrochloric acid</td>
</tr>
<tr>
<td>HBr</td>
<td>Hydrobromic acid</td>
</tr>
<tr>
<td>HI</td>
<td>Hydroiodic acid</td>
</tr>
<tr>
<td>HCN</td>
<td>Hydrocyanic acid</td>
</tr>
<tr>
<td>H₂S</td>
<td>Hydrosulfuric acid</td>
</tr>
</tbody>
</table>

*Note that these acids are aqueous solutions containing these substances.

### Table 2.8 Names of Some Oxygen-Containing Acids

<table>
<thead>
<tr>
<th>Acid</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>HNO₃</td>
<td>Nitric acid</td>
</tr>
<tr>
<td>HNO₂</td>
<td>Nitrous acid</td>
</tr>
<tr>
<td>H₂SO₃</td>
<td>Sulfurous acid</td>
</tr>
<tr>
<td>H₂SO₂</td>
<td>Sulfuric acid</td>
</tr>
<tr>
<td>H₃PO₄</td>
<td>Phosphoric acid</td>
</tr>
<tr>
<td>HC₂H₃O₂</td>
<td>Acetic acid</td>
</tr>
</tbody>
</table>
FIGURE 2.24
Overall strategy for naming chemical compounds.

- **Binary compound?**
  - Yes: Use the strategy summarized in Figure 2.23.
  - No: Polyatomic ion or ions present?
    - Yes: Name the compound using procedures similar to those for naming binary ionic compounds.
    - No: This is a compound for which naming procedures have not yet been considered.
<table>
<thead>
<tr>
<th>Ex.</th>
<th>anion</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>HClO₄</td>
<td>perchlorate</td>
<td>perchloric acid</td>
</tr>
<tr>
<td>HClO₃</td>
<td>chlorate</td>
<td>chloric acid</td>
</tr>
<tr>
<td>HClO₂</td>
<td>chlorite</td>
<td>chlorous acid</td>
</tr>
<tr>
<td>HClO</td>
<td>hypochlorite</td>
<td>hypochlorous acid</td>
</tr>
</tbody>
</table>

Table 2.8

<table>
<thead>
<tr>
<th></th>
<th>acid</th>
</tr>
</thead>
<tbody>
<tr>
<td>HNO₃</td>
<td>nitric acid</td>
</tr>
<tr>
<td>HNO₂</td>
<td>nitrous acid</td>
</tr>
<tr>
<td>H₂SO₄</td>
<td>sulfuric acid</td>
</tr>
<tr>
<td>H₂SO₃</td>
<td>sulfurous acid</td>
</tr>
<tr>
<td>H₃PO₄</td>
<td>phosphoric acid</td>
</tr>
<tr>
<td>H₃C₆H₅O₂ (CH₃COOH)</td>
<td>acetic acid</td>
</tr>
</tbody>
</table>

Check Table 2.5

Table 2.7

<table>
<thead>
<tr>
<th></th>
<th>acid</th>
</tr>
</thead>
<tbody>
<tr>
<td>HF</td>
<td>hydrofluoric acid</td>
</tr>
<tr>
<td>HCl</td>
<td>hydrochloric acid</td>
</tr>
<tr>
<td>HBr</td>
<td>hydrobromic acid</td>
</tr>
</tbody>
</table>

检查是否含O（见图2.25）