南方科技大学
SOUTHERN UNIVERSITY OF SCIENCE AND TECHNOLOGY

Chemistry
The Central Science

大学化学

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郭兴伟

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大学化学

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群聊：2025秋季大学化学郭兴伟课程群

该二维码7天内(9月17日前)有效，重新进入将更新

上课时间：周三 16:20-18:10
周五 14:00-15:50（双周）

地点 三教207

期中考试时间：11月9日14:00-16:00

答疑地点：理学院, C3053,
每周三19：00- 21：00

助教： 杨彧鉴 12331044@mail.sustech.edu.cn
杨青荷 12532160@mail.sustech.edu.cn，
荆鑫 12532149@mail.sustech.edu.cn
周若邻 zhourl2025@mail.sustech.edu.cn

A Brief Personal Introduction

About Me

- 2003 - 2007, B.S. in Chemistry, Hebei Unverisity of Technology
- 2007 - 2010, M.S., Renmin University of China, With Prof. Zhiping Li
- 20010 - 2014, Ph.D., University (LMU) of Munich, With Prof. Herbert Mayr
- 2014 - 2015, Postdoc, École Polytechnique, France, With Prof. Samir, Z. Zard
- 2015 - 2019, Postdoc, University of Basel, Switzerland, With Prof. Oliver S. Wenger
- 2019 - 2025, PI, Department of Chemistry, Tsinghua University,
- 2025 -, PI, Department of Chemistry, & Center for Advanced Light Source, SUSTech

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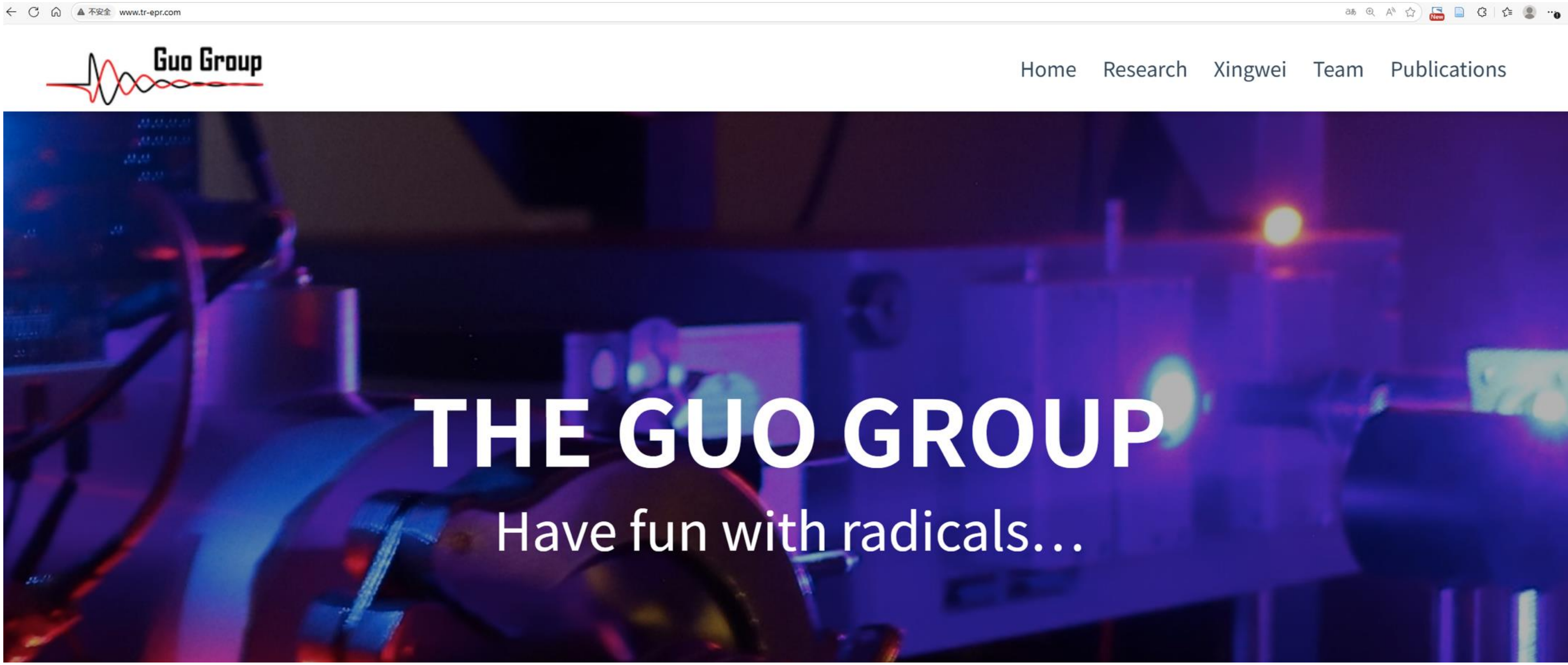
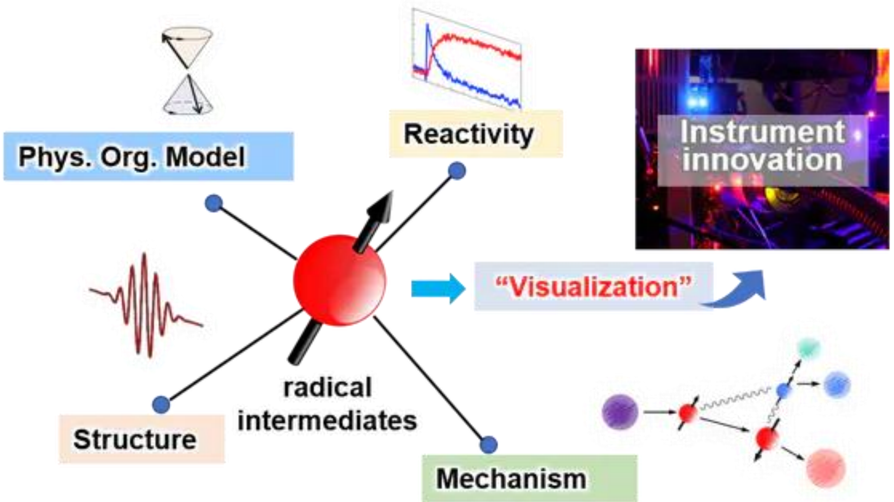


My Research

Visualizing Mechanisms in Radical Chemistry



Characterization of radical intermediates is the grand challenge in radical chemistry

Challenge

- highly reactive
- short lifetime
- low concentration
- mechanistic complexity

Demand

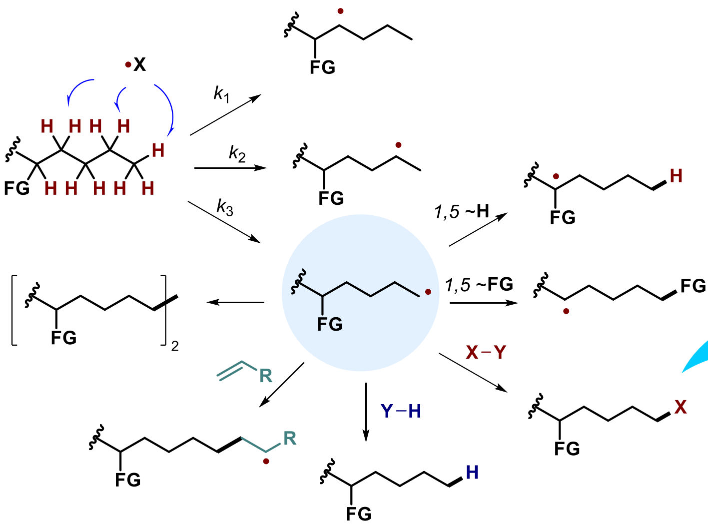
A direct observation method with:

- high time resolution
- high sensitivity
- high structure specific

My Research

Visualizing Mechanisms in Radical Chemistry

Challenge for Direct Observation of Radical Intermediates

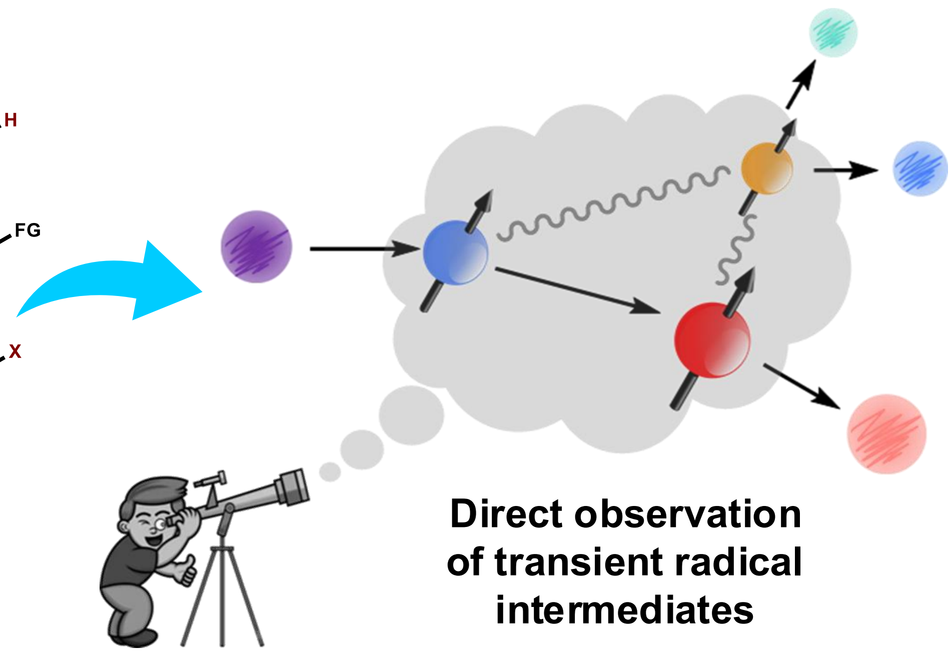


Transient radicals under reaction condition:

τ : 1~1000 μs

Conc. : 10^{-7} ~ 10^{-6} M

Numerous possible reaction pathways

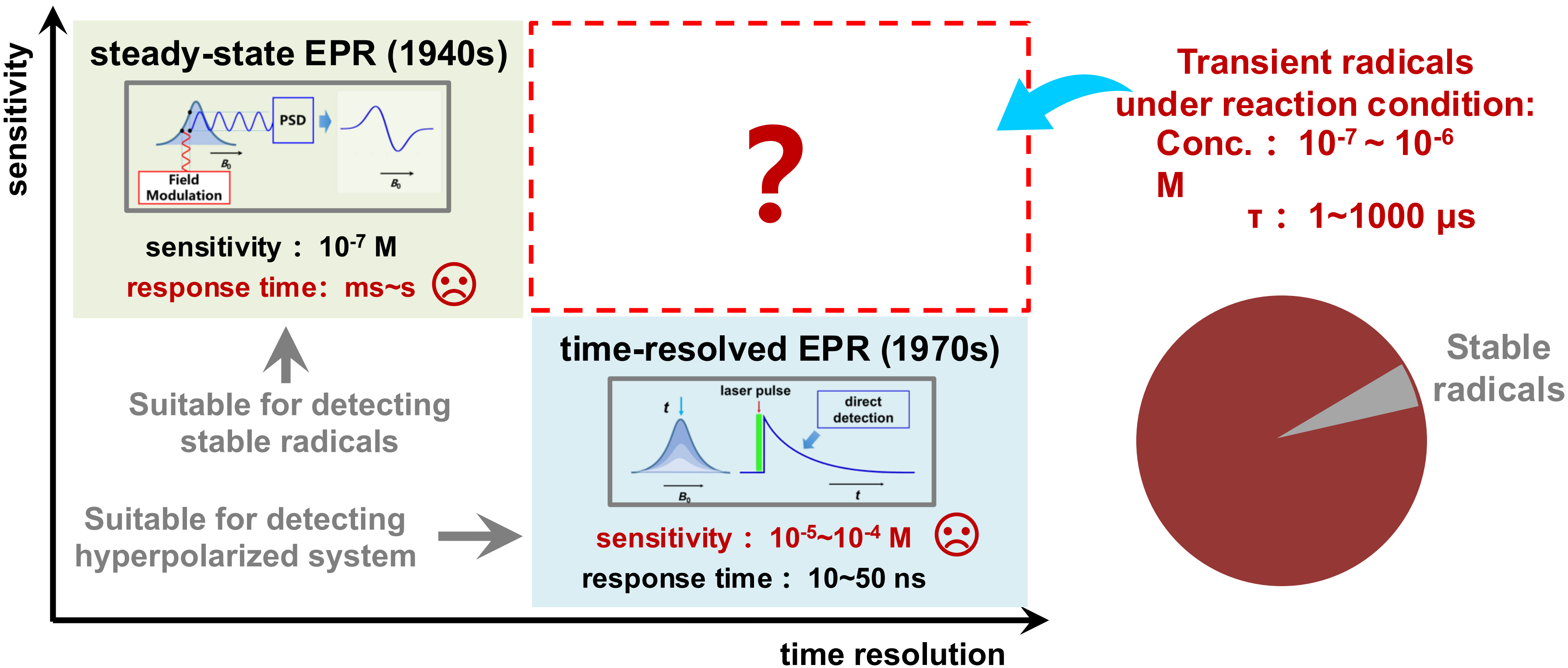


Direct observation of transient radical intermediates

My Research

Visualizing Mechanisms in Radical Chemistry

--Limitations of Current EPR Techniques--



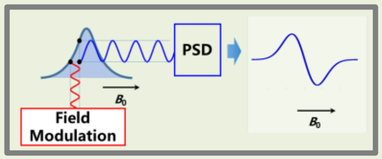
My Research

Visualizing Mechanisms in Radical Chemistry

--Limitations of Current EPR Techniques--

sensitivity

steady-state EPR (1940s)



sensitivity : 10^{-7} M

response time: ms~s ☹

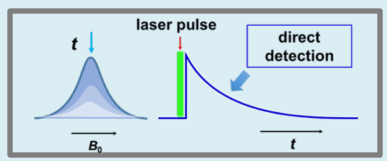
Our U-PSD TREPR

Transient radicals under reaction condition:
Conc. : 10^{-7} ~ 10^{-6} M
τ : 1~1000 μs

Suitable for detecting stable radicals

Suitable for detecting hyperpolarized system

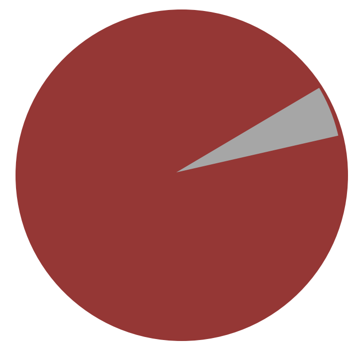
time-resolved EPR (1970s)



sensitivity : 10^{-5}~10^{-4} M ☹

response time : 10~50 ns

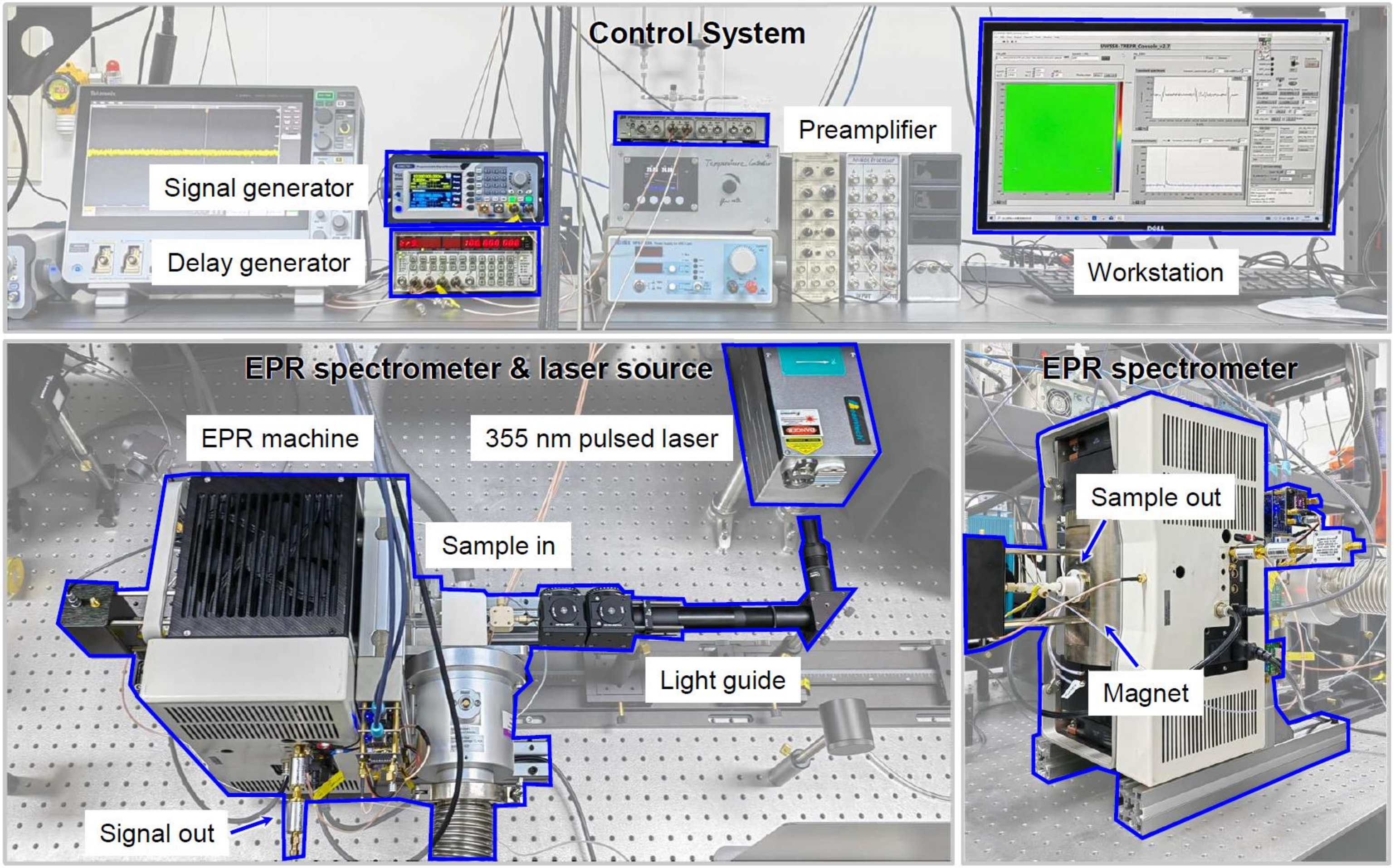
time resolution



My Research

Visualizing Mechanisms in Radical Chemistry

Our solution: U-PSD TREPR



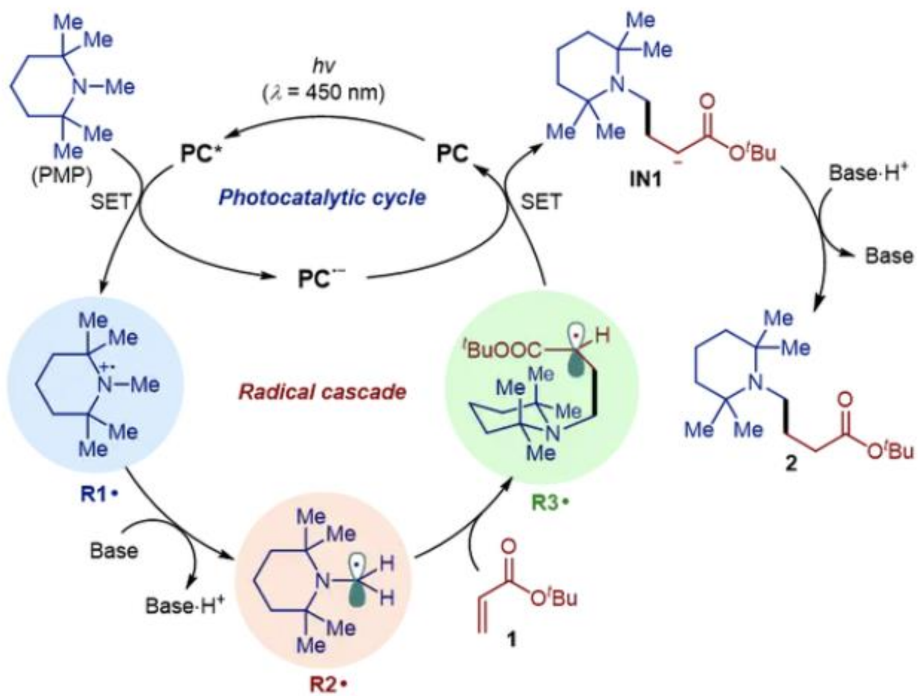
Rev. Sci. Instrum. **2023**, 94, 084101

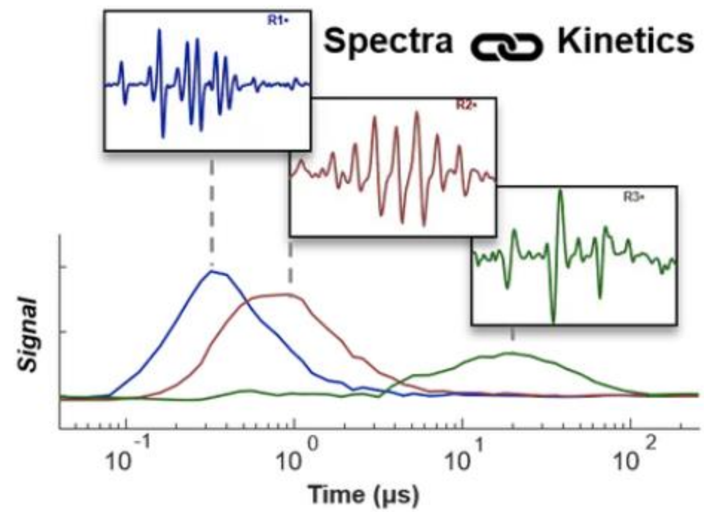
My Research

Visualizing Mechanisms in Radical Chemistry

“*Seeing the unseen*” by U-PSD TREPR

Direct observation of a full photocatalytic cycle by U-PSD TREPR

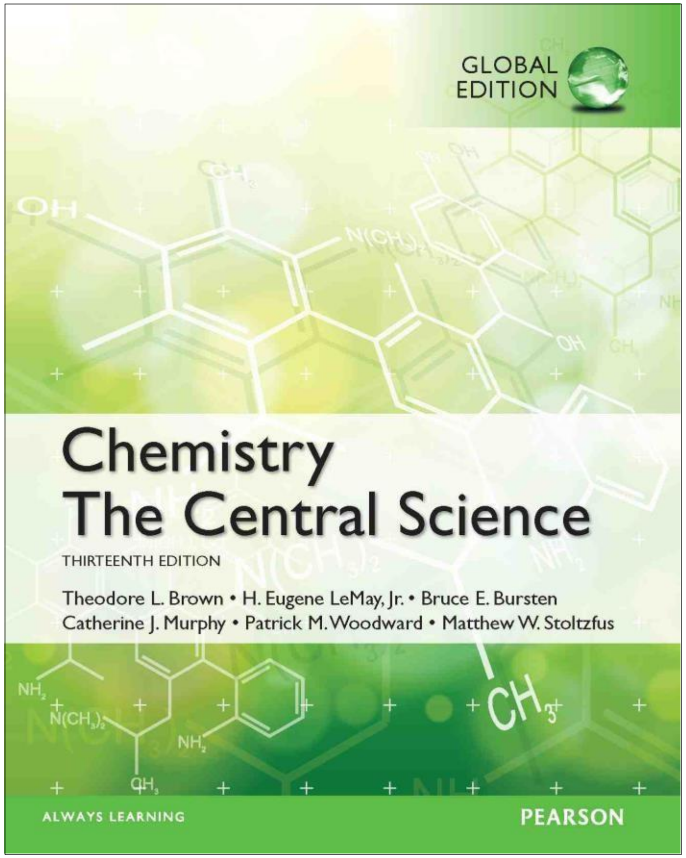




Radical Specific

Chemical Kinetics

Spin Dynamics


GLOBAL EDITION
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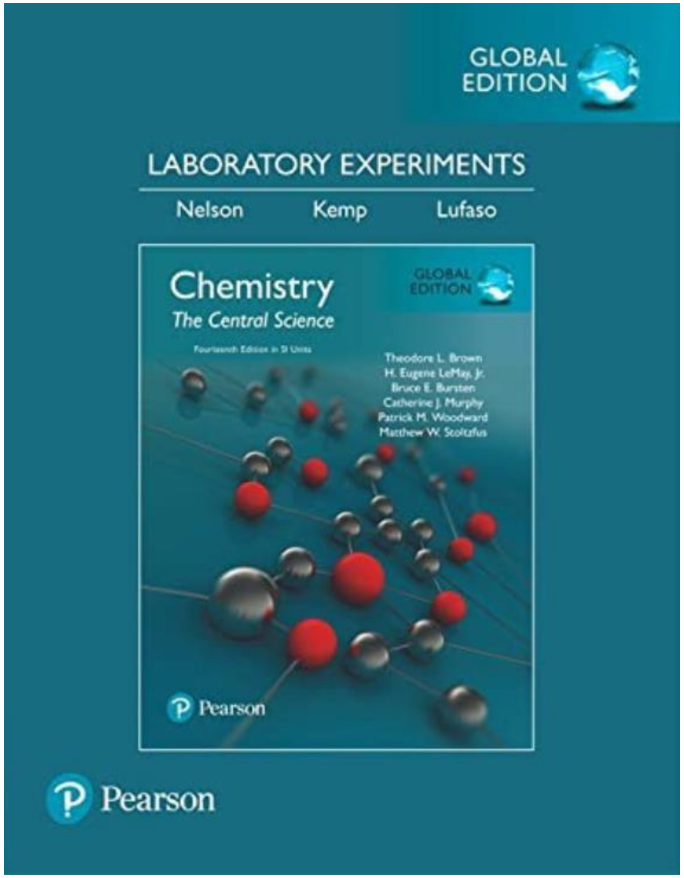
THIRTEENTH EDITION
Theodore L. Brown • H. Eugene LeMay, Jr. • Bruce E. Bursten
Catherine J. Murphy • Patrick M. Woodward • Matthew W. Stoltzfus
ALWAYS LEARNING
PEARSON


GLOBAL EDITION
LABORATORY EXPERIMENTS
Nelson
Kemp
Lufaso
Chemistry
The Central Science
Theodore L. Brown
H. Eugene LeMay, Jr.
Bruce E. Bursten
Catherine J. Murphy
Patrick M. Woodward
Matthew W. Stoltzfus
Pearson
Pearson

Lecture Schedule for 2025 Fall

(2 h) Chapter 3: Chemical Reactions and Reaction Stoichiometry
+ Significant Figures in Chapter 1
+ Nomenclature in Chapter 2

(2 h) Chapter 4: Reactions in Aqueous Solution

(4 h) Chapter 6: Electronic Structure of Atoms

(2 h) Chapter 7: Periodic Properties of the Elements

(4 h) Chapter 8: Basic Concepts of Chemical Bonding

(4 h) Chapter 9: Molecular Geometry and Bonding Theories

(2 h) Chapter 11: Liquids and Intermolecular Forces

Midterm exam (November 9, 14:00-16:00, Sunday)

(4 h) Chapter 13: Properties of Solutions

(4 h) Chapter 14: Chemical Kinetics

(4 h) Chapter 15: Chemical Equilibrium

(4 h) Chapter 16: Acid-Base Equilibria

(2 h) Chapter 17: Additional Aspects of Aqueous Equilibria

(2 h) Chapter 5: Thermochemistry

(4 h) Chapter 19: Chemical Thermodynamics

Final exam

Exams and Grading

- ❑ Quiz and homework assignment will be given
- ❑ Midterm and final exams will be given
- ❑ Final course credit will be assigned as following:

- ✓ **10% for homework assignment;**
- ✓ **20% for performance (attendance, quizzes);**
- ✓ **30% for midterm exam;**
- ✓ **40% for the final exam**

22年春季学期考试卷面平均分为74.3; 总评76.5
作业考试均为全英文卷面，请大家务必熟练掌握英文

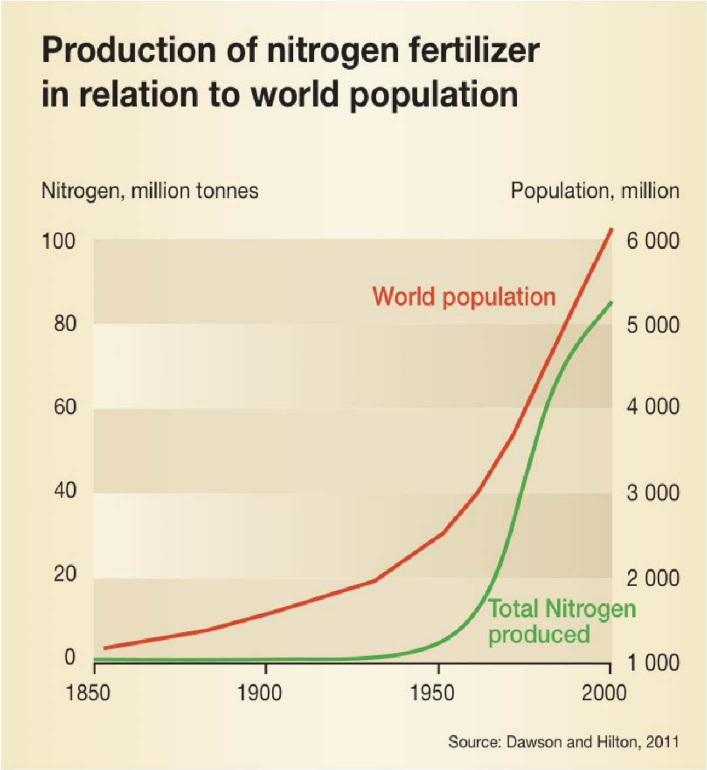
Course Objectives

Upon completing the course, a student should:

- Understand the changing nature of science
- Have a perspective of the scope of modern chemistry and its implications for society
- Display mastery of those concepts of chemistry needed to succeed in upper-level chemistry and chemistry-based courses

And hopefully and more importantly,
Love chemistry and be interested in advanced chemical research.

Haber–Bosch process



$$N_2 + 3\,H_2 \longrightarrow 2\,NH_3 \qquad \Delta H^\circ = -91.8\ \mathrm{kJ/mol}$$

230 million tonnes per year

德国卡尔斯鲁厄大学的哈伯合成氨反应器（1921）

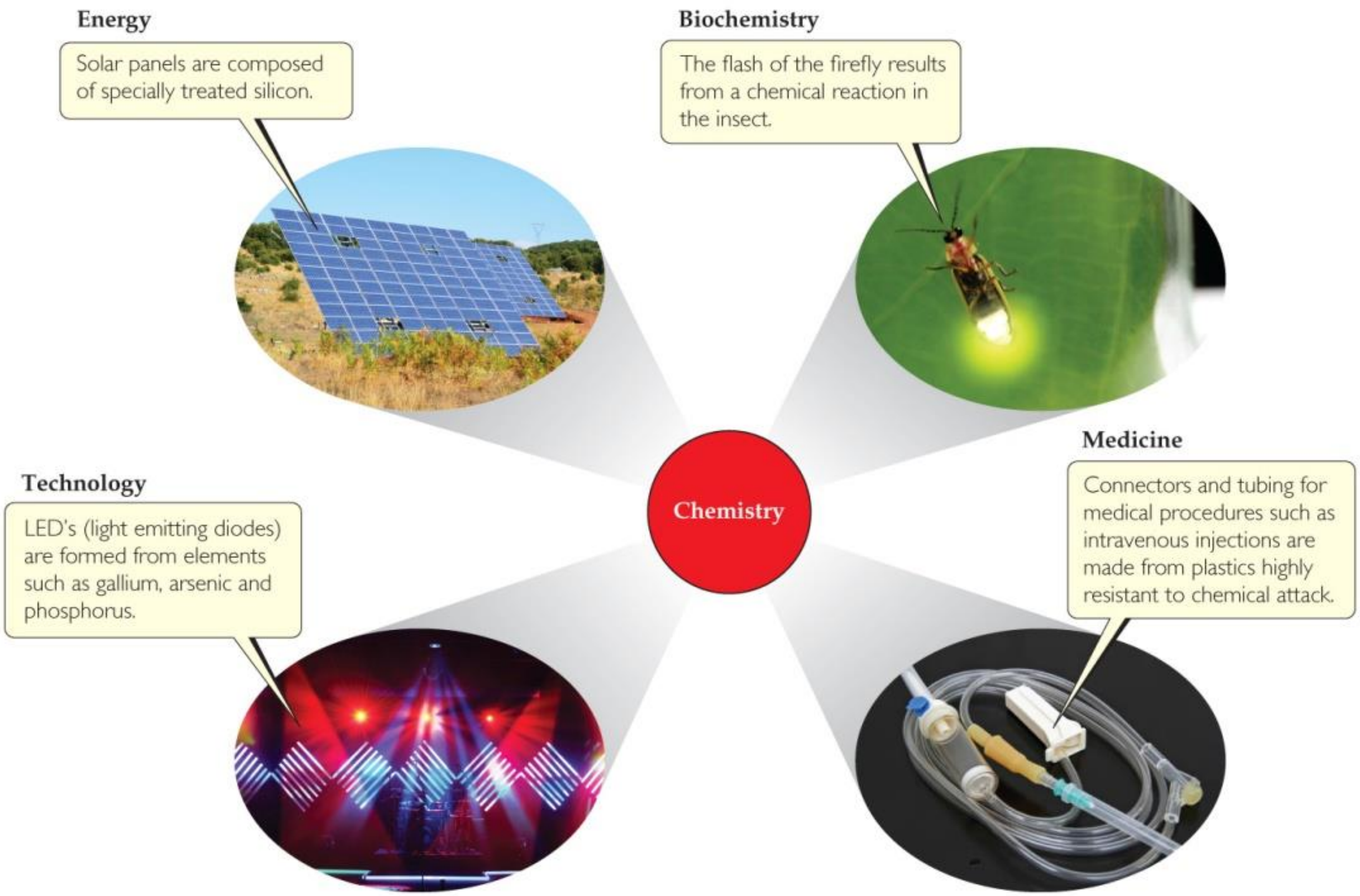
巴登
苯胺和苏打公司路德维希港 莱茵
哈伯/博世高压氨合成反应器**(1921)**

Fritz Haber (1868-1934)

The decision to award him the Nobel Prize for Chemistry in1918 was the subject of considerable controversy and criticism. The ultimate irony, however, came in 1933 when Haber was expelled from Germany because he was Jewish.

科学本身是一把双刃剑，而掌握它的科学家，永远无法摆脱其背后的伦理与道德困境。

Chemistry: CHEM is try

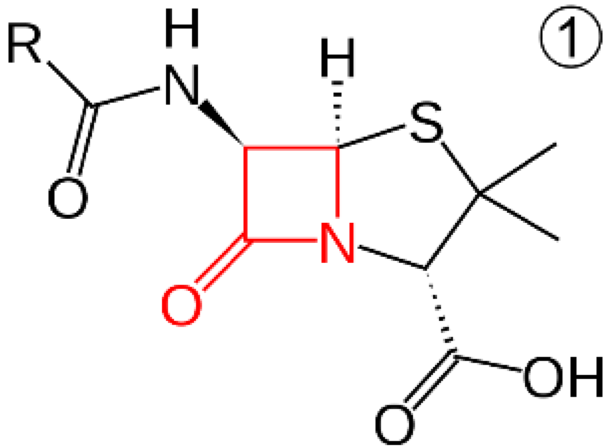


- Chemistry is the study of **matter** and the **changes** that it undergoes.
- It is central to our fundamental understanding of many science-related fields.

Chemistry around us: medicine

Howard Florey

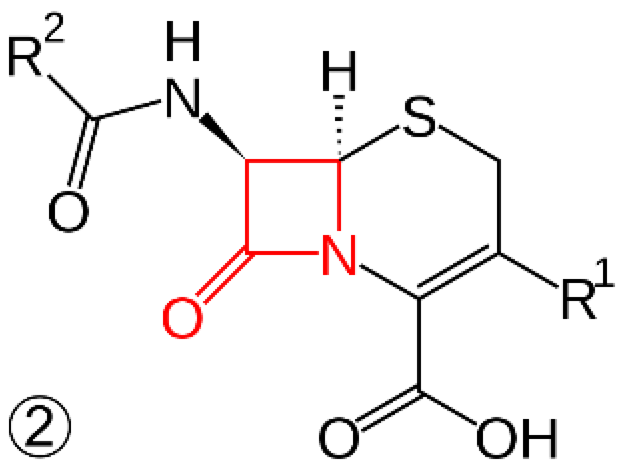
Nobel Prize in Physiology or Medicine in 1945



①

Penicillin

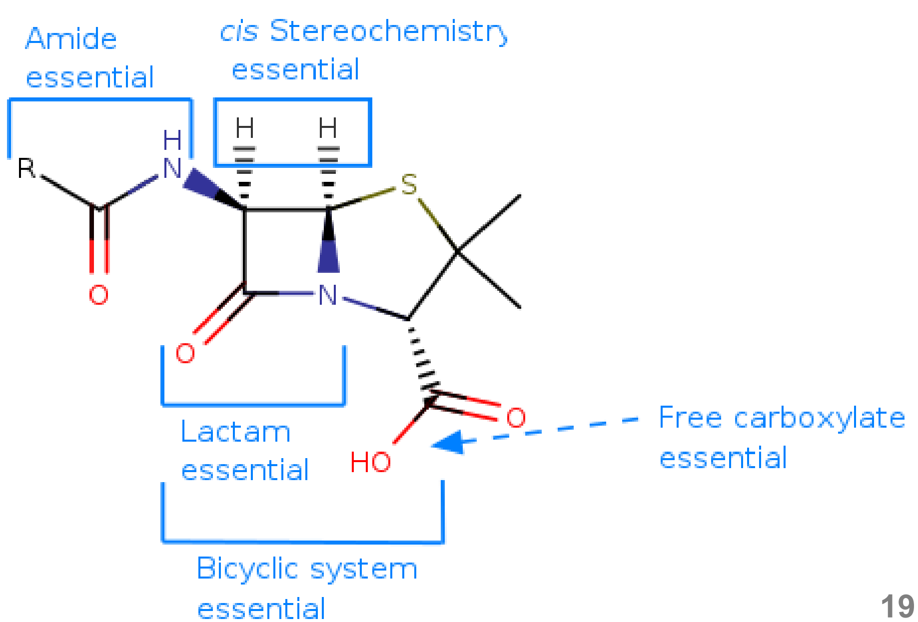
青霉素



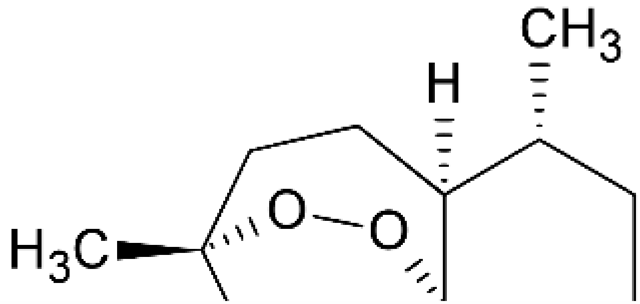
②

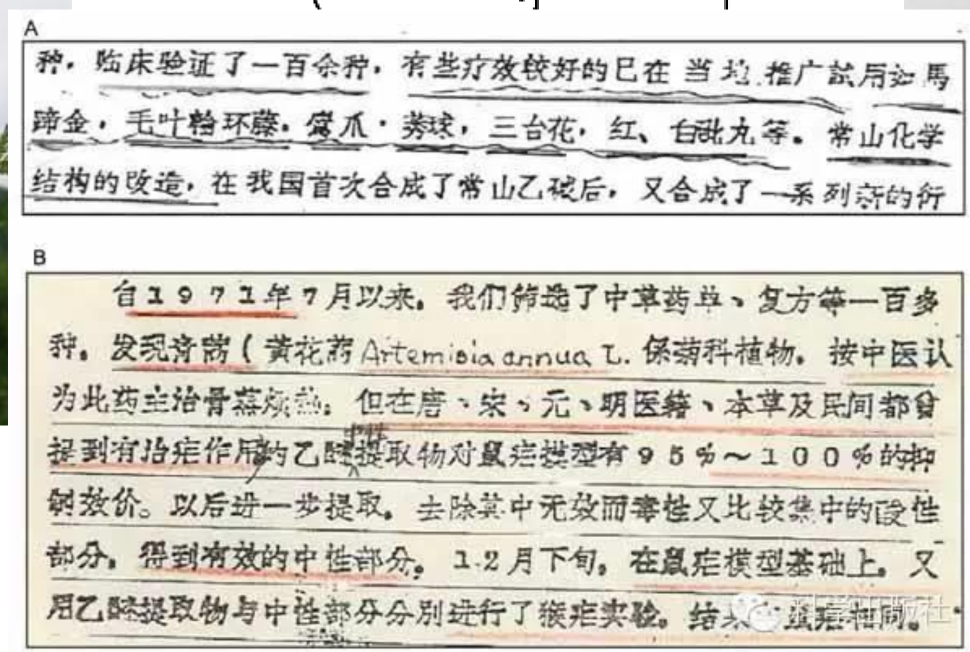
Cephalosporins

头孢



Chemistry around us: medicine





A

种，临床验证了一百余种，有些疗效较好的已在当地推广试用如马
蹄金，毛叶轮环藤，鹰爪，芬球，三台花，红、白础丸等。常山化学
结构的改造，在我国首次合成了常山乙碱后，又合成了一系列新的衍

B

自1971年7月以来，我们筛选了中草药单、复方等一百多
种，发现青蒿（黄花蒿 Artemisia annua L. 系菊科植物，按中医认
为此药主治骨蒸烦热；但在唐、宋、元、明医籍、本草及民间都曾
提到有治疟作用的乙醚提取物对鼠疟模型有95%～100%的抑
制效价。以后进一步提取，去除其中无效而毒性又比较集中的酸性
部分，得到有效的中性部分。12月下旬，在鼠疟模型基础上，又
用乙醚提取物与中性部分分别进行了猴疟实验。结果[illegible]疟指标。

ouyou Tu

bel Prize in
hysiology
dicine in 2015

Qinghaosu (

for treating Malaria (疟疾 mal aria)

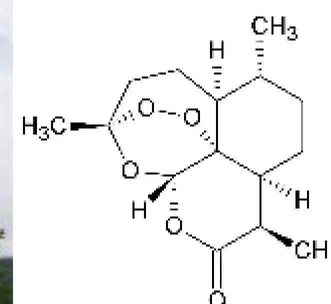
Chemistry around us: medicine

Hong Ge
(284-364)

***A Handbook of Prescriptions for Emergencies*:**
"A handful of qinghao immersed with 2 liters of water, wring out the juice and drink it all"

"青蒿一握，以水二升渍，绞取汁，尽服之"

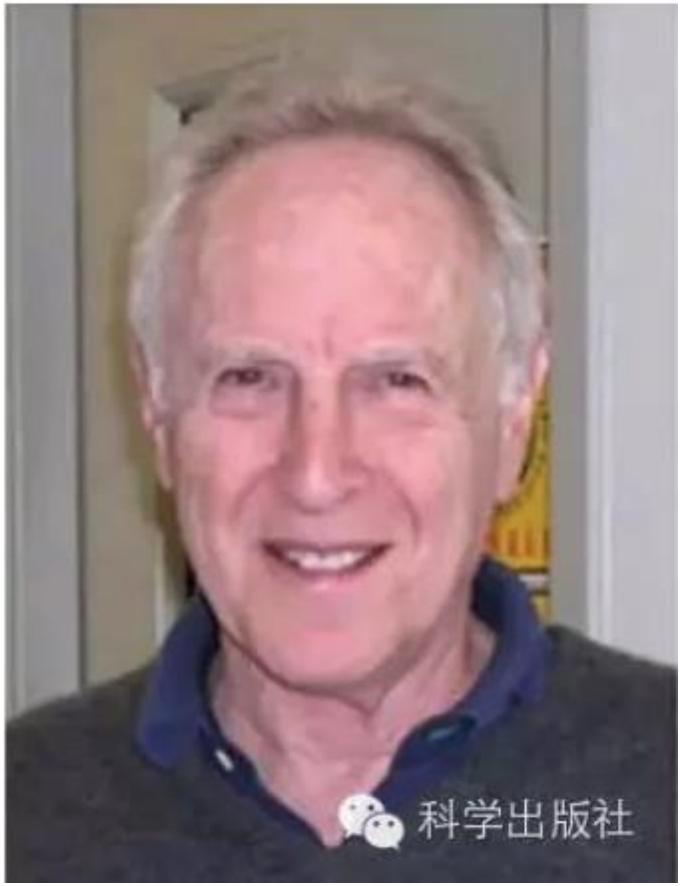
——中国晋代（340年）葛洪《肘后备急方》



Chemistry around us: medicine

Youyou Tu

the Project 523 team



Louis H. Miller

Matter

Matter is anything that has <u>mass</u> and <u>takes up space</u>.

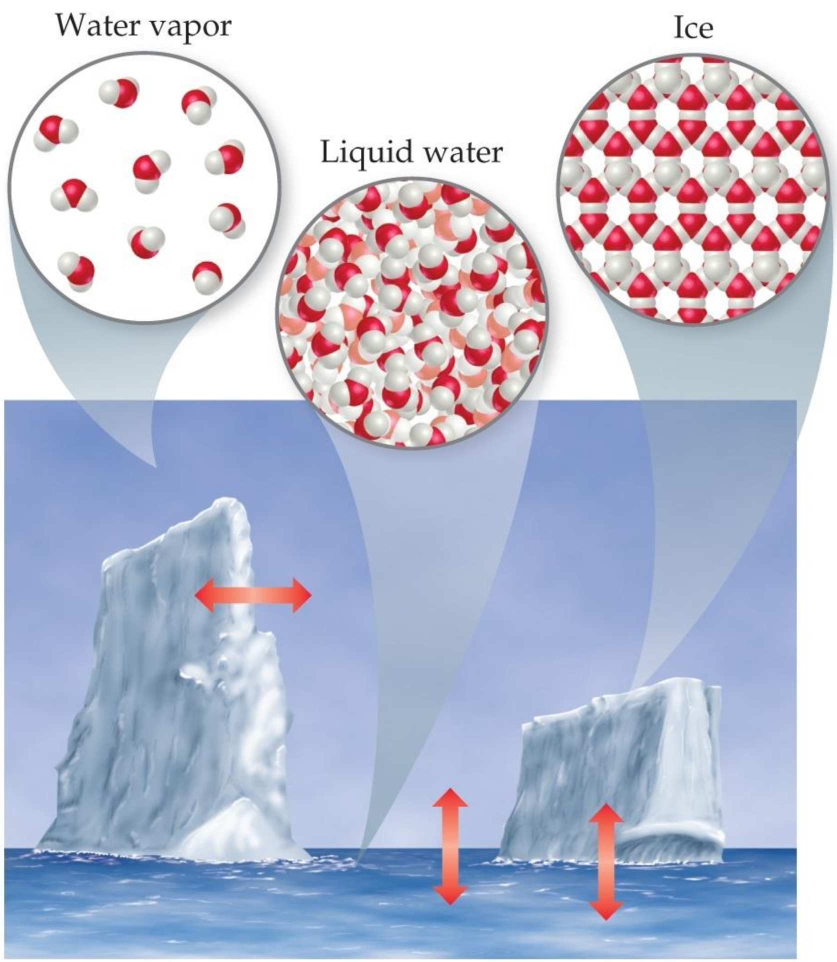
Air, water, coffee, fire, human beings, and stars are matter. Light, X-rays, photons, information, and love are not matter.

- **Atoms** are the building blocks of matter.
- Each **element (单质)** is made of a unique kind of atom.
- A **compound (化合物)** is made of two or more different kinds of elements.

Methods of Classification

- State of Matter （Macroscopic)
- Composition of Matter (submicroscopic)

States of Matter



- The three states of matter are
  1) solid.
  2) liquid.
  3) gas.
- In this figure, those states are ice, liquid water, and water vapor.

Classification of Matter Based on Composition

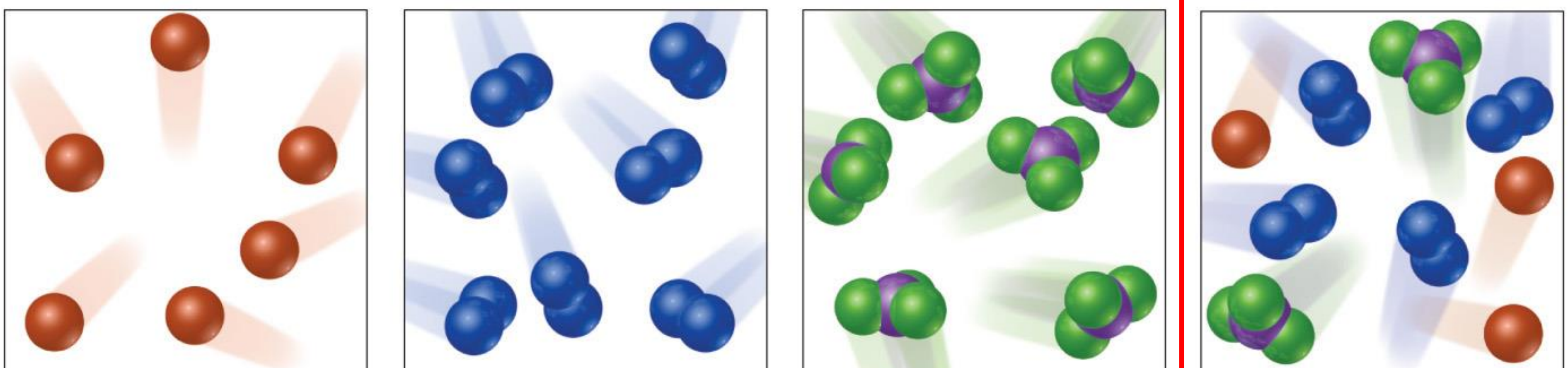
(Pure) Substance
纯净物

Element
单质

Compound
化合物

Mixture
混合物

Homogeneous
Heterogeneous



(a) Atoms of an element

(b) Molecules of an element

(c) Molecules of a compound

(d) Mixture of elements and a compound

Only one kind of atom is in any element.

Compounds must have at least two kinds of atoms.

Classification of Matter—Substances

- A **substance** has distinct properties and a composition that does not vary from sample to sample.
- The two types of substances are **elements** and **compounds**.

➢ An **element** is a substance which can *not* be decomposed to simpler substances.

➢ A **compound** is a substance which *can* be decomposed to simpler substances.

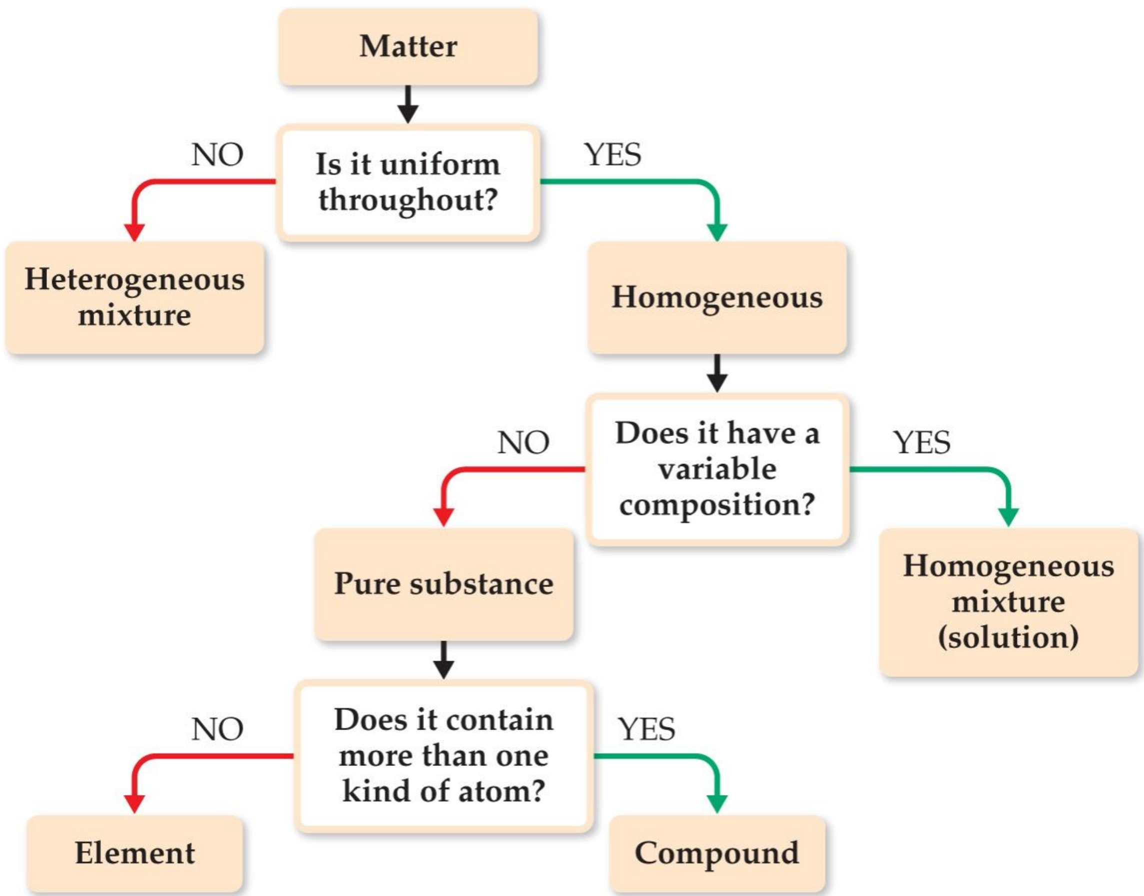
Compounds and Composition

- Compounds have a definite composition. That means that the relative number of atoms of each element that makes up the compound is the same in any sample.
- This is **The Law of Constant Composition** (or **The Law of Definite Proportions 定比定律**).

Classification of Matter—**Mixtures**

- **Mixtures** exhibit the properties of the substances that make them up.
- Mixtures can vary in composition throughout a sample (**heterogeneous**) or can have the same composition throughout the sample (**homogeneous**).
- Another name for a homogeneous mixture is **solution**.

Classification of Matter Based on Composition



- If you follow this scheme, you can determine how to classify any type of matter.

- Homogeneous mixture
- Heterogeneous mixture
- Element
- Compound

Types of Properties

- **Physical Properties** can be observed without changing a substance into another substance.
  - Some examples include boiling point, density, mass, or volume.
- **Chemical Properties** can *only* be observed when a substance is changed into another substance.
  - Some examples include flammability, corrosiveness, or reactivity with acid.

Types of Properties

- **Intensive Properties (强度性质)**

are independent of the amount of the substance that is present.

  - Examples include density, boiling point, or color.

- **Extensive Properties (广延性质)**

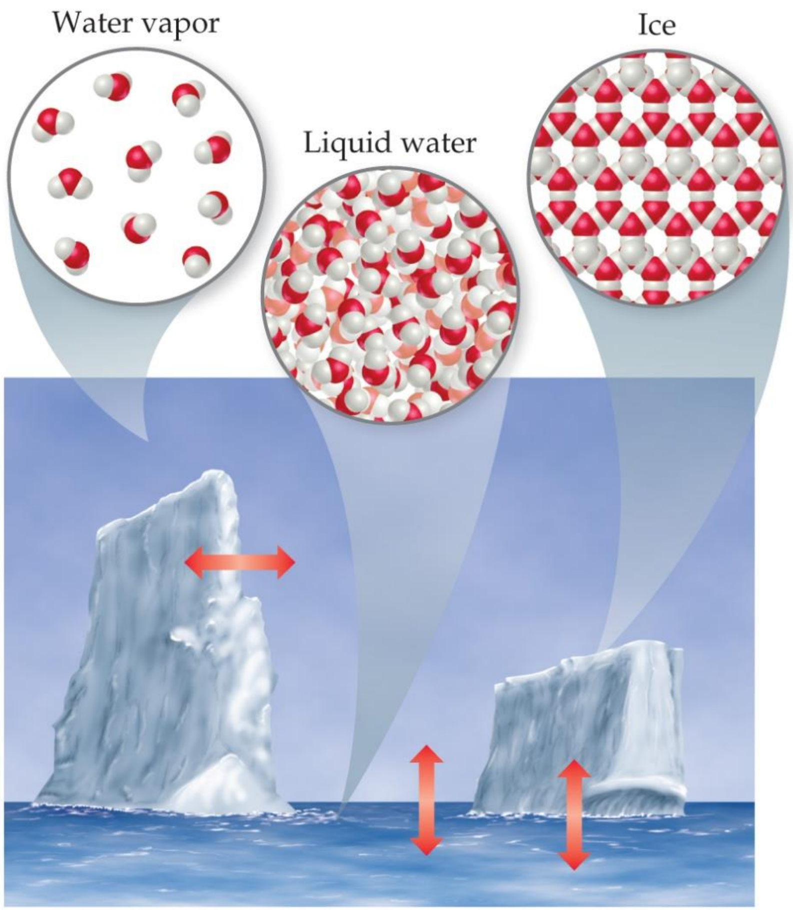
depend upon the amount of the substance present.

  - Examples include mass, volume, or energy.

Types of Changes

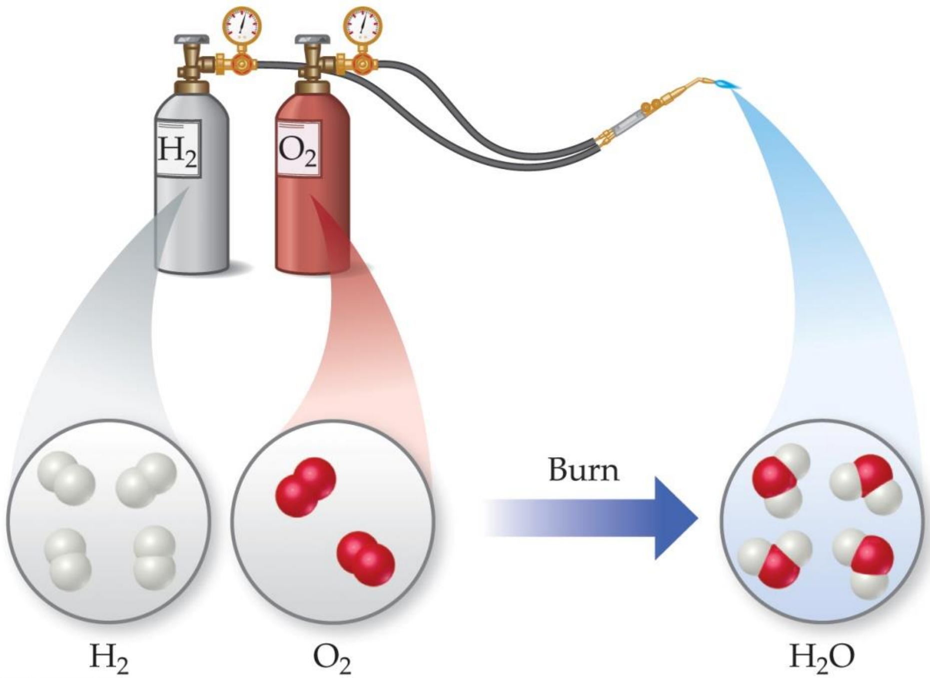
- **Physical Changes** are changes in matter that do *not* change the composition of a substance.
  - Examples include changes of state, temperature, and volume.
- **Chemical Changes** result in new substances.
  - Examples include combustion, oxidation, and decomposition.

Changes in State of Matter



- Converting between the three states of matter is a **physical change**.
- When ice melts or water evaporates, there are still 2 H atoms and 1 O atom in each molecule.

Chemical Reactions (Chemical Change)



In the course of a chemical reaction, the reacting substances are converted to new substances.

Here, the elements hydrogen and oxygen become water.

Separating Mixtures

- Mixtures can be separated based on physical properties of the components of the mixture. Some methods used are

  - filtration.
  - distillation.
  - chromatography.

Filtration (过滤)

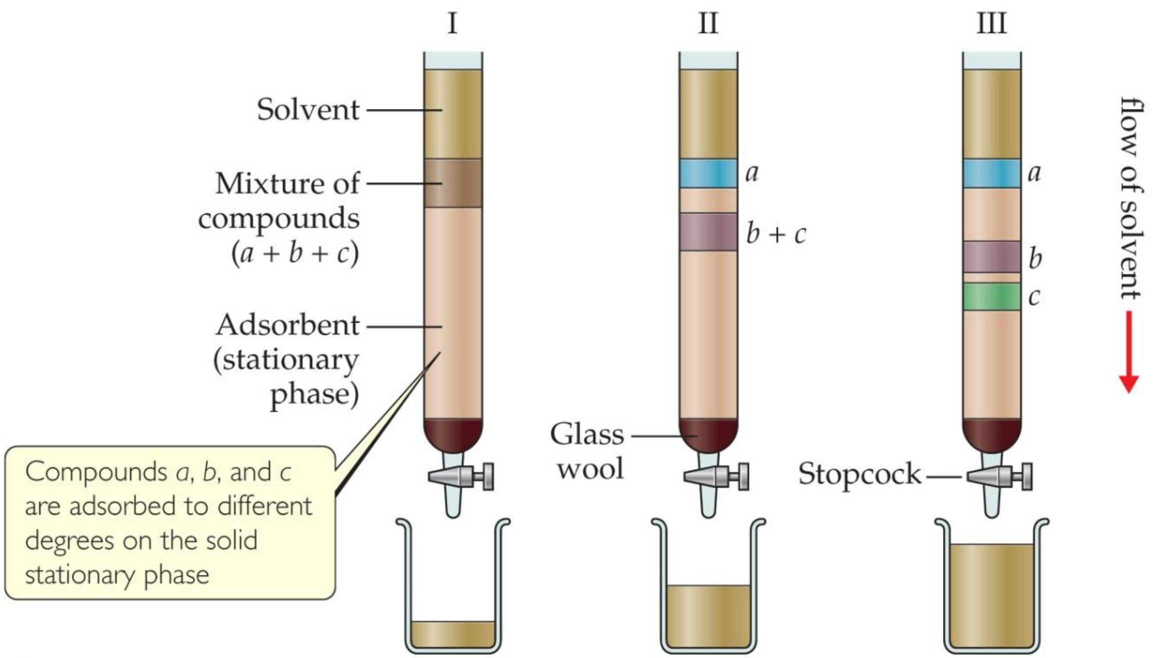
- In filtration, solid substances are separated from liquids and solutions.
- Used on Tons Scale, may take days to weeks

Distillation (蒸馏)

- Distillation uses differences in the boiling points of substances to separate a homogeneous mixture into its components.

Chromatography (色谱)

- This technique separates substances on the basis of differences in the ability of substances to adhere to the solid surface.



Descriptions of a sample that are based on the amount of substance are called

a. physical properties.
b. chemical properties.
c. intensive properties.
d. extensive properties.

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Properties that describe the way a substance reacts to form other substances are called

a. physical properties.
b. chemical properties.
c. homogeneous properties.
d. heterogeneous properties.

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Numbers and Chemistry

- Numbers play a major role in chemistry. Many topics are **quantitative** (have a numerical value).

  Exact number (1 dozen = 12, 1 kg = 1000 g = 2.2046 lb., the number of people)

  Inexact number (numbers obtained by measurement)

- Concepts of numbers in science

➢ Units of measurement

➢ Quantities that are measured and calculated

➢ Uncertainty in measurement

➢ Significant figures (有效数字)

➢ Dimensional analysis (量纲分析)

Units of Measurement—Metric System (公制计量法)

- The units used for scientific measurements are of those of the metric system.
- It was developed in France and is used as the system of measurement in most countries.
- The United States still uses the traditional English system.

Units of Measurements—SI Units (国际计量单位)

Table 1.4 SI Base Units

Physical Quantity	Name of Unit	Abbreviation
Mass	Kilogram	kg
Length	Meter	m
Time	Second	s or sec
Temperature	Kelvin	K
Amount of substance	Mole	mol
Electric current	Ampere	A or amp
Luminous intensity	Candela	cd

- *Système International d'Unités* ("The International System of Units")
- A different base unit is used for each quantity.

Units of Measurement—Prefixes in Metric System with SI units

Table 1.5 Prefixes Used in the Metric System and with SI Units

Prefix	Abbreviation	Meaning	Example	
Peta	P	10^{15}	1 petawatt (PW)	$= 1 \times 10^{15}$ watts[a]
Tera	T	10^{12}	1 terawatt (TW)	$= 1 \times 10^{12}$ watts
Giga	G	10^{9}	1 gigawatt (GW)	$= 1 \times 10^{9}$ watts
Mega	M	10^{6}	1 megawatt (MW)	$= 1 \times 10^{6}$ watts
Kilo	k	10^{3}	1 kilowatt (kW)	$= 1 \times 10^{3}$ watts
Deci	d	10^{-1}	1 deciwatt (dW)	$= 1 \times 10^{-1}$ watt
Centi	c	10^{-2}	1 centiwatt (cW)	$= 1 \times 10^{-2}$ watt
Milli	m	10^{-3}	1 milliwatt (mW)	$= 1 \times 10^{-3}$ watt
Micro	μ[b]	10^{-6}	1 microwatt (μW)	$= 1 \times 10^{-6}$ watt
Nano	n	10^{-9}	1 nanowatt (nW)	$= 1 \times 10^{-9}$ watt
Pico	p	10^{-12}	1 picowatt (pW)	$= 1 \times 10^{-12}$ watt
Femto	f	10^{-15}	1 femtowatt (fW)	$= 1 \times 10^{-15}$ watt
Atto	a	10^{-18}	1 attowatt (aW)	$= 1 \times 10^{-18}$ watt
Zepto	z	10^{-21}	1 zeptowatt (zW)	$= 1 \times 10^{-21}$ watt

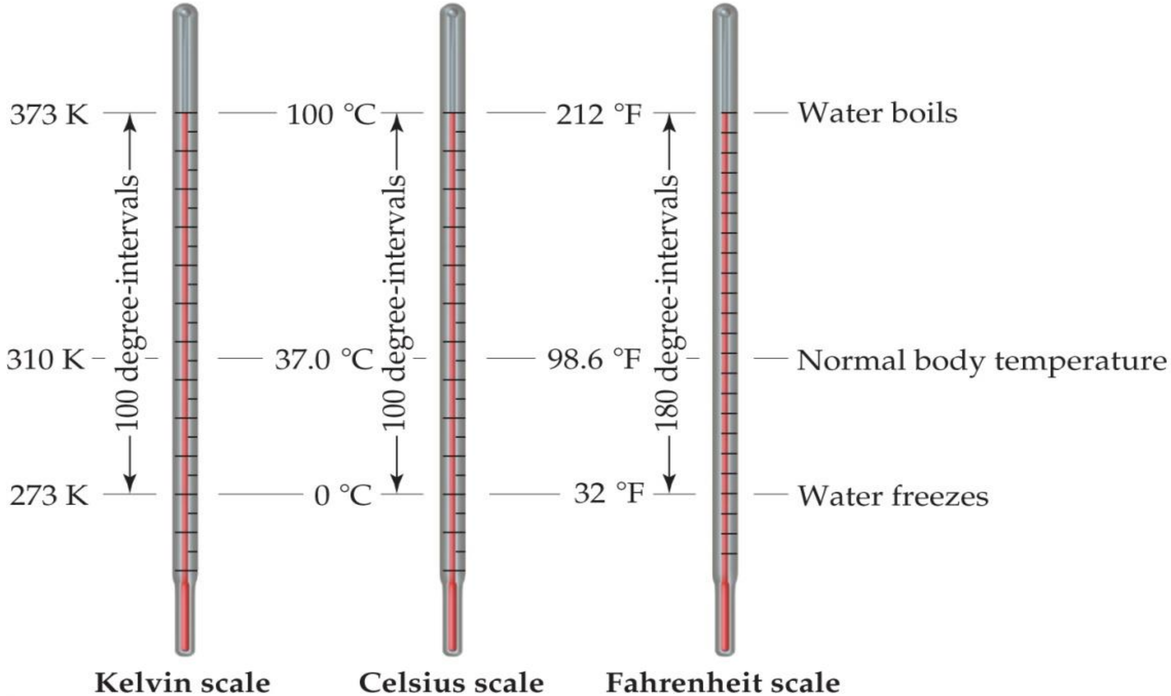
[a] The watt (W) is the SI unit of power, which is the rate at which energy is either generated or consumed. The SI unit of energy is the joule (J); $1 \text{ J} = 1 \text{ kg} \cdot \text{m}^2/\text{s}^2$ and $1 \text{ W} = 1 \text{ J/s}$.
[b] Greek letter mu, pronounced "mew."

- Prefixes convert the base units into units that are appropriate for common usage or appropriate measure.

Temperature

❑ In general usage, **temperature** is considered the "hotness and coldness" of an object that determines the direction of heat flow.

❑ Heat flows spontaneously from an object with a higher temperature to an object with a lower temperature.



K ^oC ^oF

Temperature

- In scientific measurements, the Celsius (摄氏) and Kelvin (开氏) scales are most often used.
- The Celsius scale is based on the properties of water.
  - 0 °C is the freezing point of water.
  - 100 °C is the boiling point of water.
- The **Kelvin** is the SI unit of temperature.
  - It is based on the properties of gases.
  - There are no negative Kelvin temperatures.
  - The lowest possible temperature is called absolute zero (0 K).
    - **K = °C + 273.15**

Temperature

- The Fahrenheit scale (华氏) is not used in scientific measurements, but you hear about it in weather reports in US!
- The equations below allow for conversion between the Fahrenheit and Celsius scales:

$$°F = 9/5(°C) + 32$$

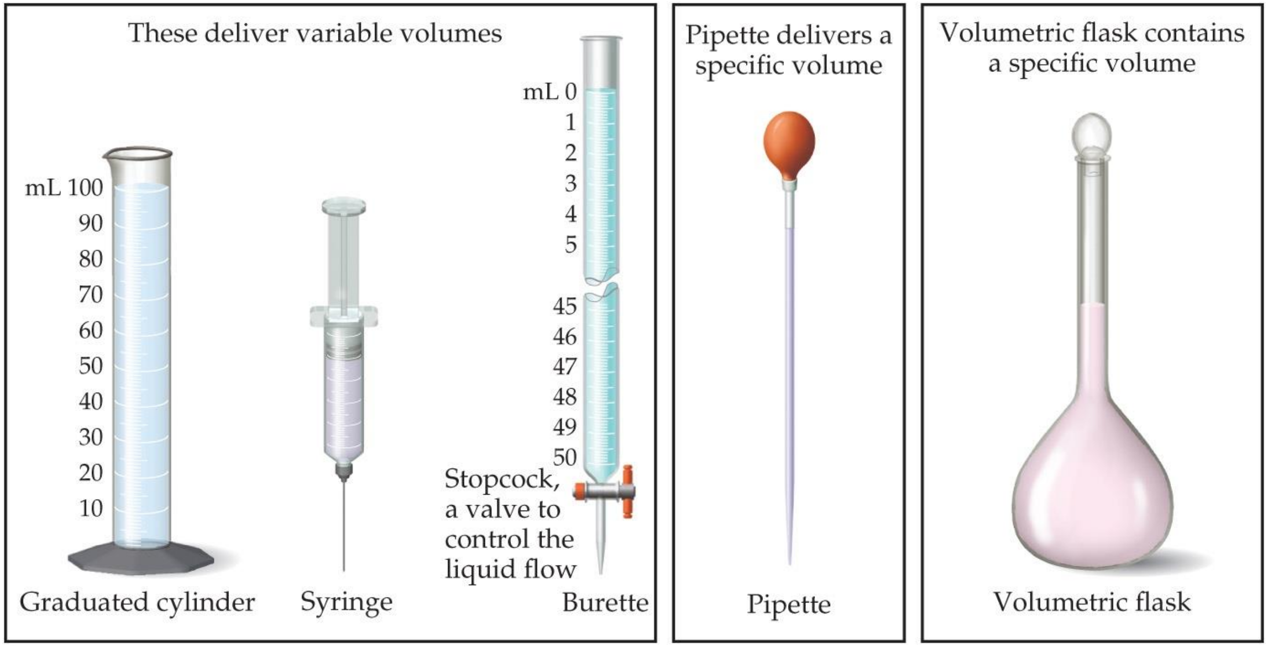
$$°C = 5/9(°F - 32)$$

Numbers Encountered in Science

- **Exact** numbers (精确数) are counted or given by definition. For example, there are 12 eggs in 1 dozen.
- **Inexact** (or **measured**) numbers depend on how they were determined. Scientific instruments have limitations. Some balances measure to ±0.01 g; others measure to ±0.0001g.

Uncertainty in Measurements

- Different measuring devices have different uses and different degrees of accuracy (?).
- All measured numbers have some degree of inaccuracy.



Accuracy versus Precision

- **Accuracy (准确度)** refers to the proximity of a measurement to the true value of a quantity.

- **Precision (精密度)** refers to the proximity of several measurements to each other.

Good accuracy
Good precision

Poor accuracy
Good precision

Poor accuracy
Poor precision

Significant Figures (有效数字)

- The term **significant figures** refers to digits that were measured.
- When rounding calculated numbers, we pay attention to significant figures so we do not overstate the accuracy of our answers.

Significant Figures (*)

1. All nonzero digits are significant.
2. Zeroes between two significant figures are themselves significant.
3. Zeroes at the beginning of a number are never significant.
4. Zeroes at the end of a number are significant **if** a decimal point is written in the number.

Sample Exercise 1.7

Significant Figures

- When addition or subtraction is performed, answers are rounded to **the least significant decimal place**.

  the rightmost digit of a number that has a decimal point

- When multiplication or division is performed, answers are rounded to the number of digits that corresponds to the ***least* number of significant figures** in any of the numbers used in the calculation.

- exact number ====

  infinite number of significant figures

Sample exercise 1.8
Sample exercise 1.9

Atomic Theory of Matter

- 460-370 BC， Democritus and other Greek philosophers, atomos = indivisible or uncuttable.
- Later, Plato and Aristotle disagreed, no ultimately indivisible particles
- In the early nineteenth century, the theory that **atoms** are the fundamental building blocks of matter reemerged in championed by John Dalton.

Dalton's Postulates

Dalton's Atomic Theory

1. Each element is composed of extremely small particles called atoms.

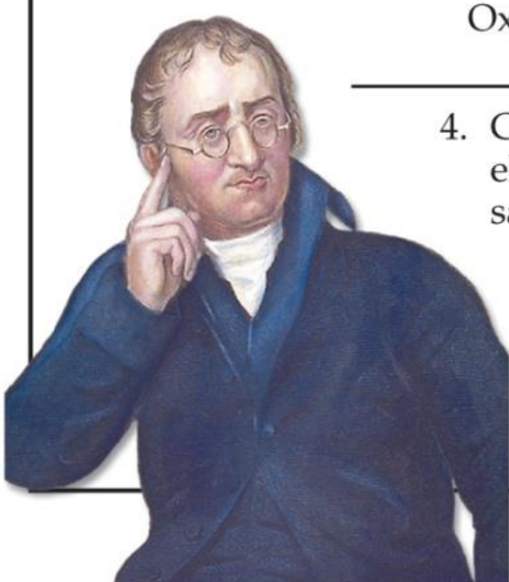
An atom of the element oxygen — An atom of the element nitrogen

2. All atoms of a given element are identical, but the atoms of one element are different from the atoms of all other elements.

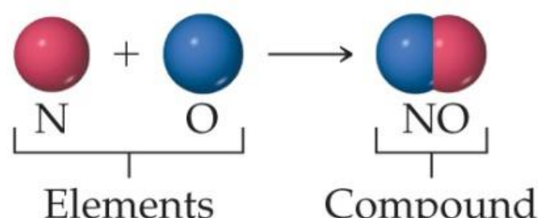
Oxygen — Nitrogen

3. Atoms of one element cannot be changed into atoms of a different element by chemical reactions; atoms are neither created nor destroyed in chemical reactions.

Oxygen ⇸ Nitrogen

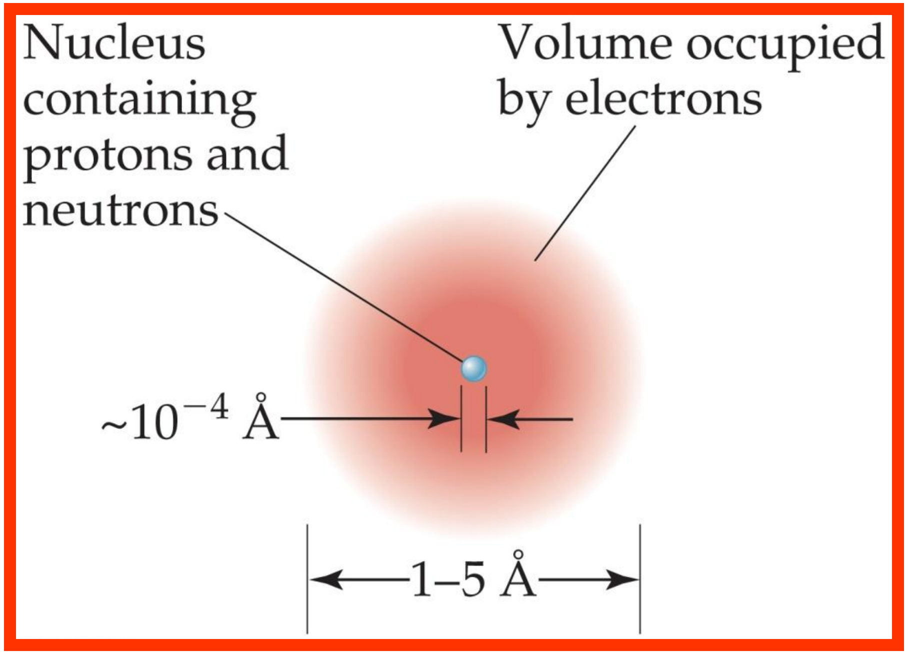


4. Compounds are formed when atoms of more than one element combine; a given compound always has the same relative number and kind of atoms.



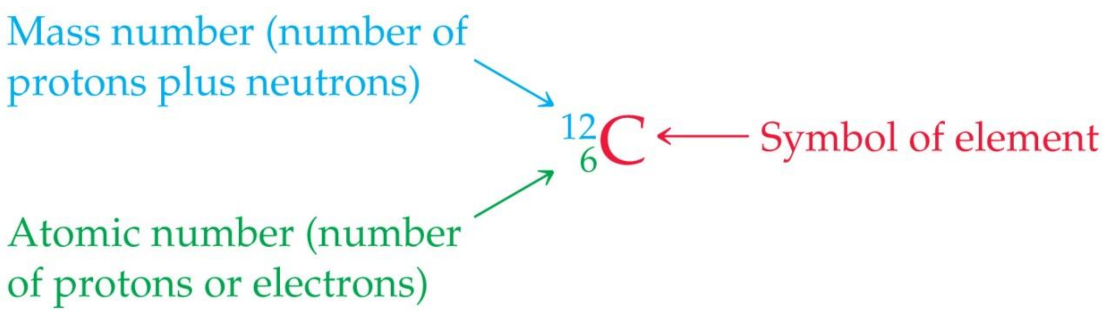
The Nuclear Atom （核型原子）

- Rutherford postulated a very small, dense nucleus with the electrons around the outside of the atom.
- Most of the volume is empty space.
- Atoms are very small; 1 – 5 Å or 100 – 500 pm.



- Other subatomic particles (protons were discovered in 1919 by Rutherford, and neutrons in 1932 by Chadwick) were discovered.

Symbols of Elements



- Elements are represented by a one or two letter **symbol (元素符号)**. This is the symbol for carbon.
- All atoms of the same element have the same number of protons, which is called the **atomic number**, *Z*. (原子数) It is written as a subscript BEFORE the symbol.
- The **mass number** (质量数) is the total number of protons and neutrons in the nucleus of an atom. It is written as a superscript BEFORE the symbol.

Atomic Weight (原子量)

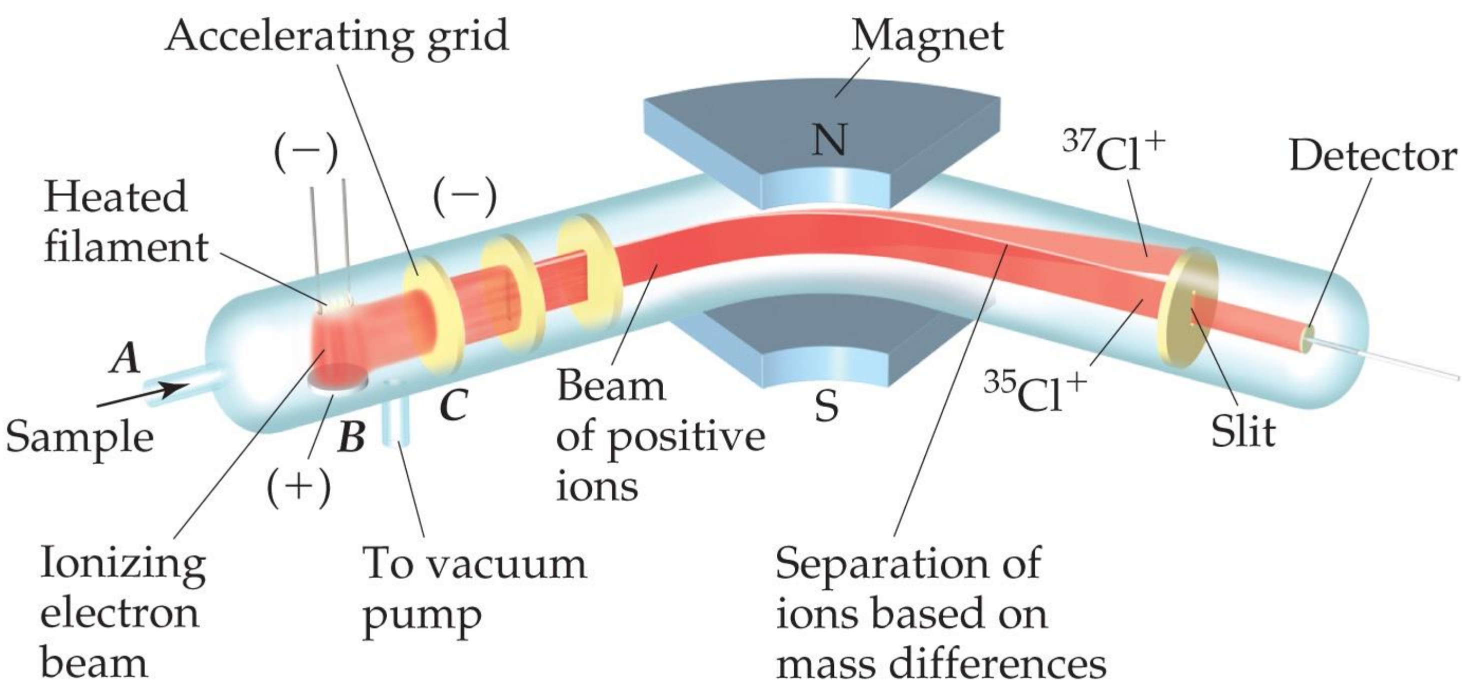
- Because <u>in the real world</u> we use large amounts of atoms and molecules, we use average masses in calculations.
- **An average mass** is found using all isotopes of an element weighted by their relative abundances. This is the element's **atomic weight**.

Atomic Weight = Σ [(isotope mass) × (fractional natural abundance)].

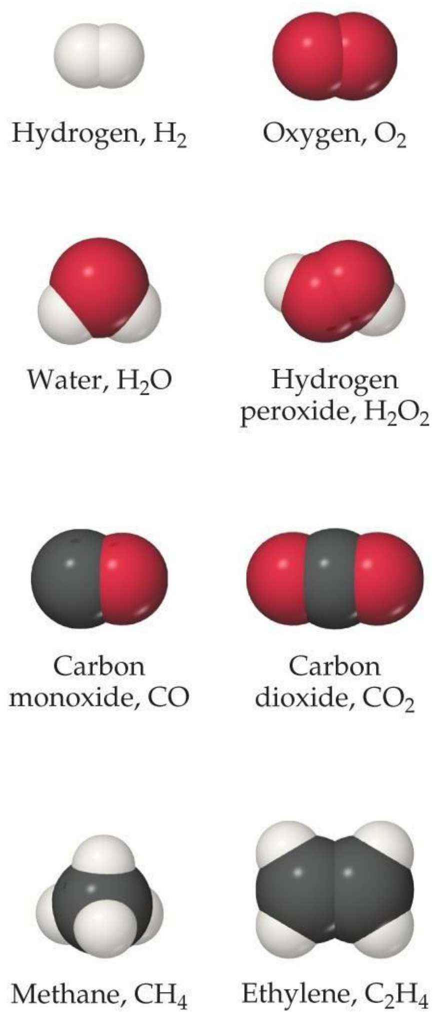
Note: the sum is for ALL isotopes of an element.

Atomic Weight Measurement

- Atomic and molecular weight can be measured with great accuracy using a mass spectrometer (质谱).



Chemical Formulas (化学式)



- The **subscript** to the right of the symbol of an element tells the number of atoms of that element in one molecule of the compound.
- **Molecular compounds (分子化合物)** are composed of molecules and almost always contain only nonmetals.

He **H_2** **H_2O**

Diatomic Molecules

- These seven elements occur naturally as molecules containing two atoms:
  - Hydrogen H_2
  - Nitrogen N_2
  - Oxygen O_2
  - Fluorine F_2
  - Chlorine Cl_2
  - Bromine Br_2
  - Iodine I_2

Types of Formulas

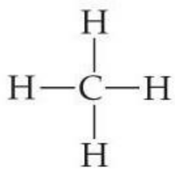
- **Empirical formulas (最简式)** give the lowest whole-number ratio of atoms of each element in a compound.
- **Molecular formulas (分子式)** give the exact number of atoms of each element in a compound.
- If we know the molecular formula of a compound, we can determine its empirical formula. The converse is not true!

Glucose: $C_6H_{12}O_6$

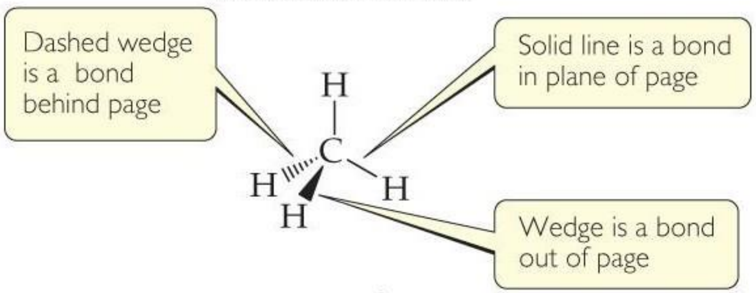
Types of Formulas

CH_4

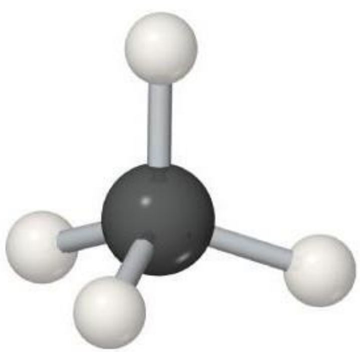
Molecular formula



Structural formula



Perspective drawing



Ball-and-stick model

Space-filling model

- **Structural formulas** show the order in which atoms are attached. They do NOT depict the three-dimensional shape of molecules.
- **Perspective drawings** also show the three-dimensional order of the atoms in a compound. These are also demonstrated using **models**.

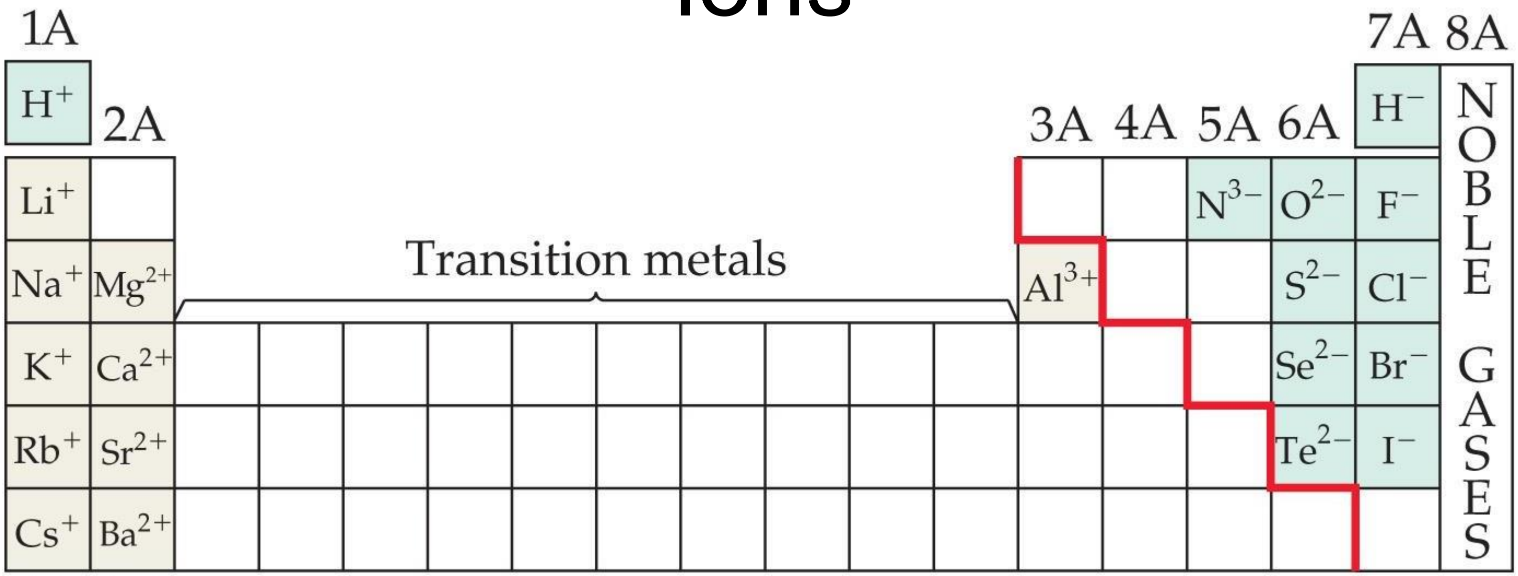
The Periodic Table of the Elements

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

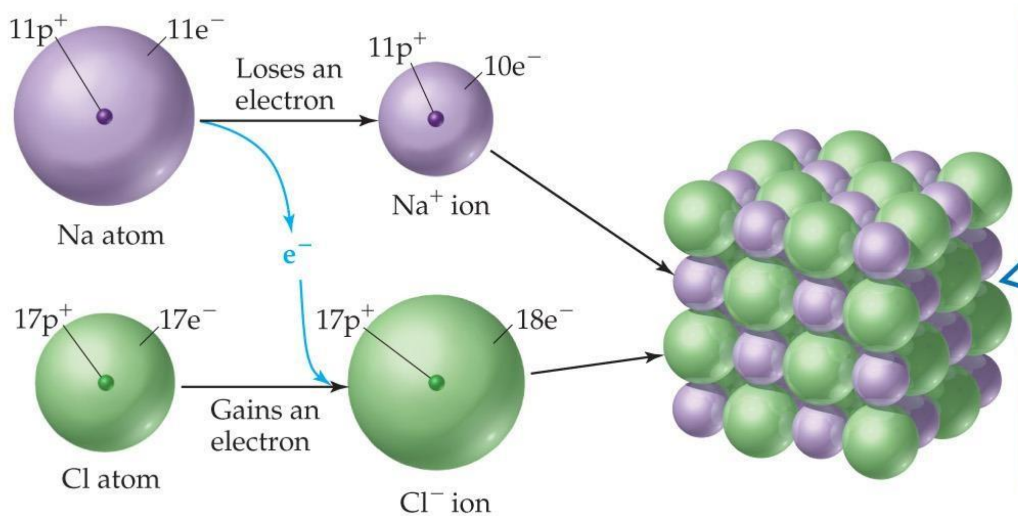
Ions



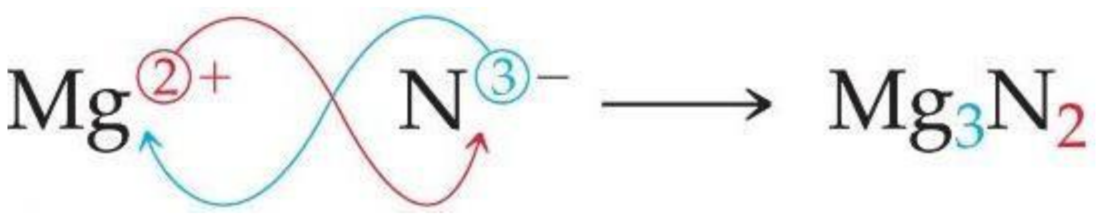
- When an atom of a group of atoms loses or gains electrons, it becomes an **ion**.
- **Cations (阳离子, cat-ion)** are formed when at least one electron is **lost**. Monatomic cations are formed by metals.
- **Anions (阴离子, An-ion)** are formed when at least one electron is **gained**. Monatomic anions are formed by nonmetals.

Ionic Compounds (离子化合物)

- **Ionic compounds** (such as NaCl) are generally formed between metals and nonmetals.
- Electrons are transferred from the metal to the nonmetal. The oppositely charged ions attract each other. Only empirical formulas are written.



Writing Formulas



- Because compounds are electrically neutral, one can determine the formula of a compound this way:
  - The charge on the cation becomes the subscript on the **anion**.
  - The charge on the anion becomes the subscript on the **cation**.
  - If these subscripts are not in the lowest whole-number ratio, divide them by the greatest common factor.

Inorganic Nomenclature (命名法)

- **Cation ions: single charge, different charges, nonmetal**
- **Anion: monatomic, oxyanion**
- **Ionic compound: Cation + Anion**

Inorganic Nomenclature (命名法)

1. Cations

a. *Cations formed from metal atoms have the same name as the metal:*

Na^{+}	sodium ion	Zn^{2+}	zinc ion	Al^{3+}	aluminum ion

b. *If a metal can form cations with different charges, the positive charge is indicated by a Roman numeral in parentheses following the name of the metal:*

Fe^{2+}	iron(II) ion	Cu^{+}	copper(I) ion
Fe^{3+}	iron(III) ion	Cu^{2+}	copper(II) ion

Ions of the same element that have different charges have different pro such as different colors (◀ Figure 2.21).

Fe^{2+}	ferrous ion	Cu^{+}	cuprous ion
Fe^{3+}	ferric ion	Cu^{2+}	cupric ion

Although we will only rarely use these older names in this text, you might encounter them elsewhere.

c. *Cations formed from nonmetal atoms have names that end in* -ium:

NH_4^{+}	ammonium ion	H_3O^{+}	hydronium ion

These two ions are the only ions of this kind that we will encounter frequently in the text.

Common Cations

Table 2.4 Common Cations[a]

Charge	Formula	Name	Formula	Name
1+	**H^+**	**hydrogen ion**	**NH_4^+**	**ammonium ion**
	Li^+	lithium ion	Cu^+	copper(I) or cuprous ion
	Na^+	**sodium ion**		
	K^+	**potassium ion**		
	Cs^+	cesium ion		
	Ag^+	**silver ion**		
2+	**Mg^{2+}**	**magnesium ion**	Co^{2+}	cobalt(II) or cobaltous ion
	Ca^{2+}	**calcium ion**	**Cu^{2+}**	**copper(II)** or cupric ion
	Sr^{2+}	strontium ion	**Fe^{2+}**	**iron(II)** or ferrous ion
	Ba^{2+}	barium ion	Mn^{2+}	manganese(II) or manganous ion
	Zn^{2+}	**zinc ion**	Hg_2^{2+}	mercury(I) or mercurous ion
	Cd^{2+}	cadmium ion	**Hg^{2+}**	**mercury(II)** or mercuric ion
			Ni^{2+}	nickel(II) or nickelous ion
			Pb^{2+}	**lead(II)** or plumbous ion
			Sn^{2+}	tin(II) or stannous ion
3+	**Al^{3+}**	**aluminum ion**	Cr^{3+}	chromium(III) or chromic ion
			Fe^{3+}	**iron(III)** or ferric ion

[a]The ions we use most often in this course are in boldface. Learn them first.

Inorganic Nomenclature (命名法)

2. Anions

a. *The names of monatomic anions are formed by replacing the ending of the name of the element with* -ide:

H^-	hydride ion	O^{2-}	oxide ion	N^{3-}	nitride ion

A few polyatomic anions also have names ending in *-ide*:

OH^-	hydroxide ion	CN^-	cyanide ion	O_2^{2-}	peroxide ion

b. *Polyatomic anions containing oxygen have names ending in either* -ate *or* -ite *and are called* **oxyanions**. The *-ate* is used for the most common or representative oxyanion of an element, and *-ite* is used for an oxyanion that has the same charge but one O atom fewer:

NO_3^-	nitrate ion	SO_4^{2-}	sulfate ion
NO_2^-	nitrite ion	SO_3^{2-}	sulfite ion

Prefixes are used when the series of oxyanions of an element extends to four members, as with the halogens. The prefix *per-* indicates one more O atom than the oxyanion ending in *-ate; hypo-* indicates one O atom fewer than the oxyanion ending in *-ite*:

ClO_4^-	perchlorate ion (one more O atom than chlorate)
ClO_3^-	chlorate ion
ClO_2^-	chlorite ion (one O atom fewer than chlorate)
ClO^-	hypochlorite ion (one O atom fewer than chlorite)

Common Anions

Table 2.5 Common Anions[a]

Charge	Formula	Name	Formula	Name
1−	H^-	hydride ion	**CH_3COO^-** (or $C_2H_3O_2^-$)	**acetate ion**
	F^-	**fluoride ion**	ClO_3^-	chlorate ion
	Cl^-	**chloride ion**	**ClO_4^-**	**perchlorate ion**
	Br^-	**bromide ion**	**NO_3^-**	**nitrate ion**
	I^-	**iodide ion**	MnO_4^-	permanganate ion
	CN^-	cyanide ion		
	OH^-	**hydroxide ion**		
2−	**O^{2-}**	**oxide ion**	**CO_3^{2-}**	**carbonate ion**
	O_2^{2-}	peroxide ion	CrO_4^{2-}	chromate ion
	S^{2-}	**sulfide ion**	$Cr_2O_7^{2-}$	dichromate ion
			SO_4^{2-}	**sulfate ion**
3−	N^{3-}	nitride ion	**PO_4^{3-}**	**phosphate ion**

[a]The ions we use most often are in boldface. Learn them first.

Patterns in Oxyanion Nomenclature

Maximum of three O atoms in period 2.

	Group 4A	Group 5A	Group 6A	Group 7A
Period 2	CO_3^{2-} **Carbonate ion**	NO_3^- **Nitrate ion**		
Period 3		PO_4^{3-} **Phosphate ion**	SO_4^{2-} **Sulfate ion**	ClO_4^- **Perchlorate ion**

Maximum of four O atoms in period 3.

Charges increase right to left.

- Central atoms on the second row have a bond to, at most, three oxygens; those on the third row take up to four.
- Charges increase as you go from *right* to *left*.

Patterns in Oxyanion Nomenclature

Simple anion: ________ide (chloride, Cl^-)

Oxyanions: per______ate (perchlorate, ClO_4^-) $\xleftarrow{+\text{O atom}}$ ________ate (chlorate, ClO_3^-) $\xrightarrow{-\text{O atom}}$ ________ite (chlorite, ClO_2^-) $\xrightarrow{-\text{O atom}}$ hypo____ite (hypochlorite, ClO^-)

Common or representative oxyanion

Maximum of three O atoms in period 2.

	Group 4A	Group 5A	Group 6A	Group 7A
Period 2	CO_3^{2-} **Carbonate ion**	NO_3^- **Nitrate ion**		
Period 3		PO_4^{3-} **Phosphate ion**	SO_4^{2-} **Sulfate ion**	ClO_4^- **Perchlorate ion**

Charges increase right to left.

Maximum of four O atoms in period 3.

Inorganic Nomenclature (命名法)

3. Ionic Compounds

Names of ionic compounds consist of the cation name followed by the anion name:

$CaCl_2$	calcium chloride
$Al(NO_3)_3$	aluminum nitrate
$Cu(ClO_4)_2$	copper(II) perchlorate (or cupric perchlorate)

In the chemical formulas for aluminum nitrate and copper(II) perchlorate, parentheses followed by the appropriate subscript are used because the compounds contain two or more polyatomic ions.

Nomenclature of Binary Molecular Compounds

Table 2.6 Prefixes Used in Naming Binary Compounds Formed between Nonmetals

Prefix	Meaning
Mono-	*1*
Di-	*2*
Tri-	*3*
Tetra-	*4*
Penta-	*5*
Hexa-	*6*
Hepta-	*7*
Octa-	*8*
Nona-	*9*
Deca-	*10*

- The name of the element farther to the left in the periodic table (closer to the metals) or lower in the same group is usually written first.
- A prefix is used to denote the number of atoms of each element in the compound (***mono-*** is not used on the first element listed, however).

Nomenclature of Binary Compounds

- The ending on the second element is changed to ***-ide***.
  - CO_2: carbon dioxide
  - CCl_4: carbon tetrachloride
- If the prefix ends with *a* or *o* and the name of the element begins with a vowel, the two successive vowels are often elided into one.
  - N_2O_5: dinitrogen pentoxide

The following examples illustrate these rules:

Cl_2O	dichlorine monoxide	NF_3	nitrogen trifluoride
N_2O_4	dinitrogen tetroxide	P_4S_{10}	tetraphosphorus decasulfide

Acid Nomenclature

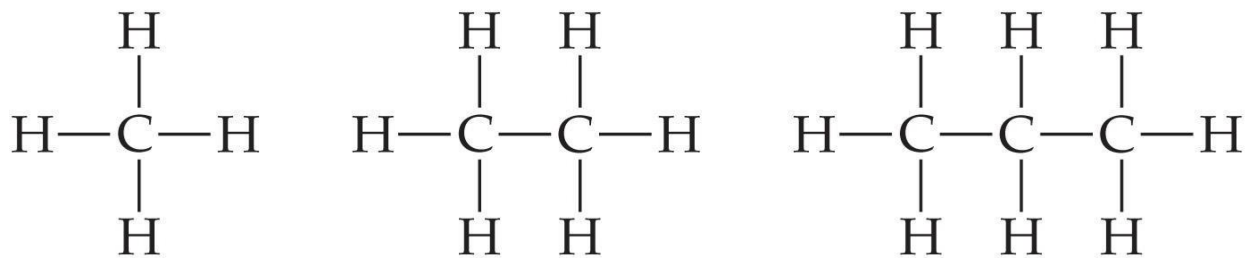
Anion		Acid
__________ide (chloride, Cl^-)	add H^+ ions →	hydro______ic acid (hydrochloric acid, HCl)
__________ate (chlorate, ClO_3^-) (perchlorate, ClO_4^-)	add H^+ ions →	__________ic acid (chloric acid, $HClO_3$) (perchloric acid, $HClO_4$)
__________ite (chlorite, ClO_2^-) (hypochlorite, ClO^-)	add H^+ ions →	__________ous acid (chlorous acid, $HClO_2$) (hypochlorous acid, $HClO$)

- If the anion in the acid ends in ***-ide***, change the ending to ***-ic acid*** and add the prefix ***hydro-***.
  - HCl: hydrochloric acid
  - HBr: hydrobromic acid
  - HI: hydroiodic acid

- If the anion ends in ***-ate***, change the ending to ***-ic acid.***
  - $HClO_3$: chloric acid
  - $HClO_4$: perchloric acid

- If the anion ends in ***-ite***, change the ending to ***-ous acid***.
  - HClO: hypochlorous acid
  - $HClO_2$: chlorous acid

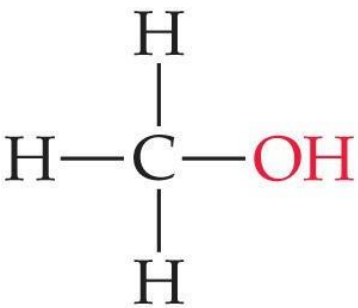
Nomenclature of Organic Compounds



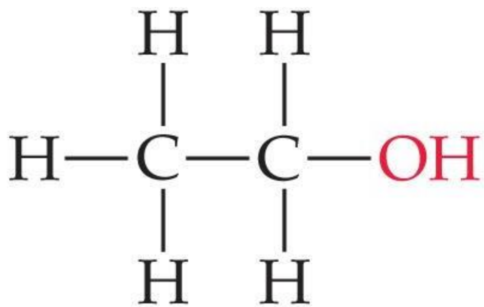
Methane Ethane Propane

- **Organic chemistry** is the study of carbon.
- Organic chemistry has its own system of nomenclature.
- The simplest hydrocarbons (compounds containing only carbon and hydrogen) are **alkanes**.
- The first part of the names just listed correspond to the number of carbons (***meth-*** = 1, ***eth-*** = 2, ***prop-*** = 3, etc.).

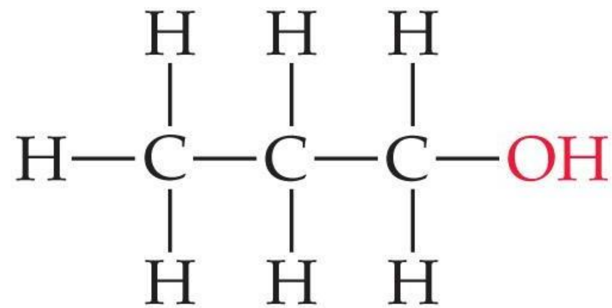
Nomenclature of Organic Compounds



Methanol



Ethanol



1-Propanol

- When a hydrogen in an alkane is replaced with something else (a **functional group**, like -OH in the compounds above), the name is derived from the name of the alkane.
- The ending denotes the type of compound.
  – An **alcohol** ends in -*ol*.

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