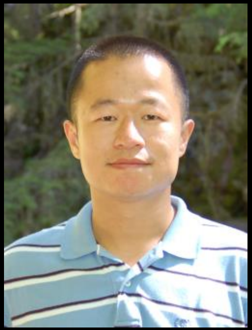
General Chemistry



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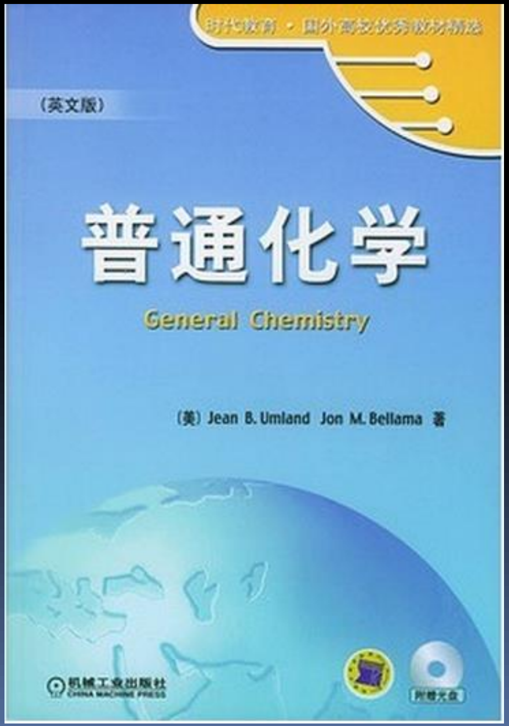
Course Webpage:

http://www.nanolab.fudan.edu.cn/teaching1.html

Course Related

- Time: Mon, class 3—4
- Reference book:
  - General Chemistry – Jean Umland & Jon Bellama
  - Class handouts
- Exams
  - One mid-term exam (30%)
  - One final exam (70%)
  - Attendance and Homework (0%)



Campus Map

復旦大學
校园地图
邯郸校区
N
比例尺1:50
We are here.
Chem Building
化学楼
光华楼
北区学生公寓
东区学生公寓

Course Overview – 1st Semester

- Introduction (Chapter 1—3)
- Electronic Structures and Periodic Table (Chapter 7—8)
- Chemical Bonds, Valence Bond Method, and Molecular Shape (Chapter 9)
- Molecular Orbital Method and Molecular Interactions (Chapter 10)
- Solution (Chapter 4)
- Acids and Bases (Chapter 15, 16.1—16.4)
- Precipitate (Chapter 16.5—16.8)

Course Overview – 2nd Semester

- Oxidation-Reduction Reaction (Chapter 11)
- Changes in States, Colligative Properties, and Phase Diagram (Chapter 5, 12, 13.5—13.7)
- Chemical Thermodynamics and Thermochemistry (Chapter 6)
- Chemical Equilibrium (Chapter 14, 17)
- Chemical Kinetics (Chapter 18)
- Electrochemistry (Chapter 19)

PART 1 – Introduction

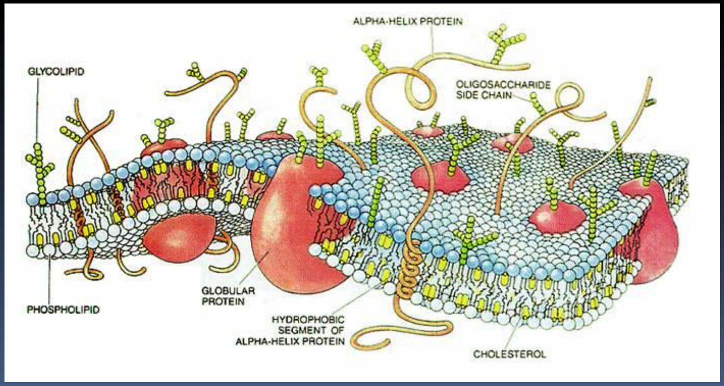
Reference: Chapter 1—3 in textbook

Importance of Chemistry

Food

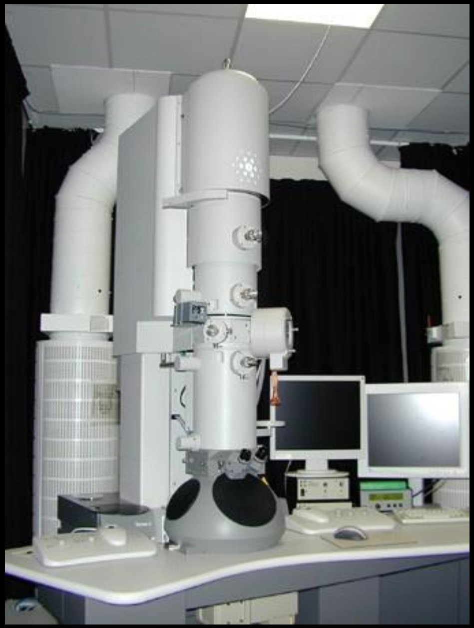
Manufacture

Energy



Biology

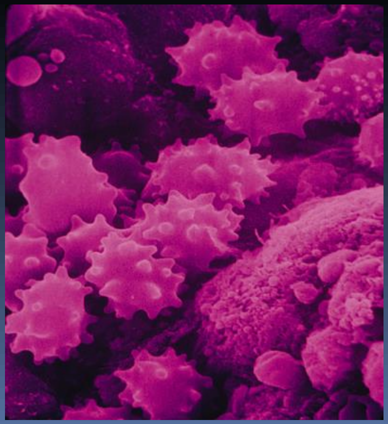
New Instrumentation & Technology

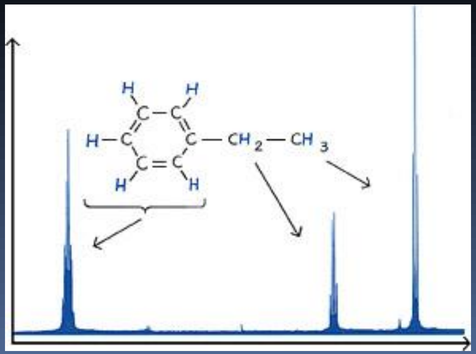


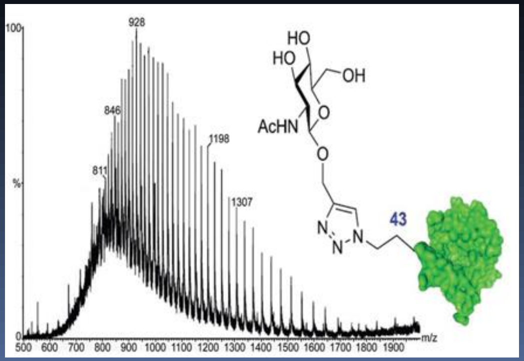
Electron Microscopy

Nuclear Magnetic Resonance

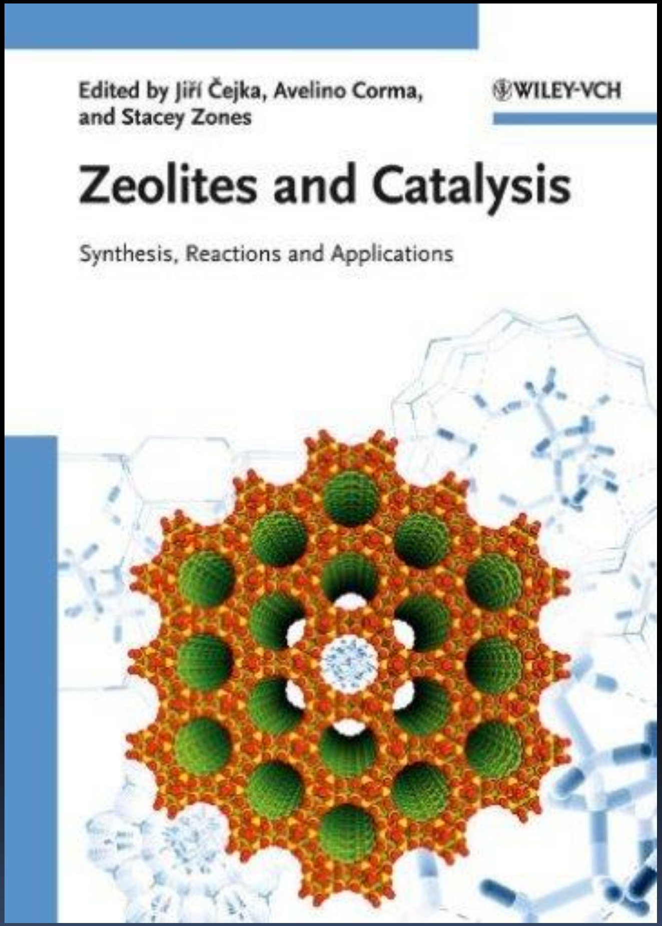
Mass Spectroscopy

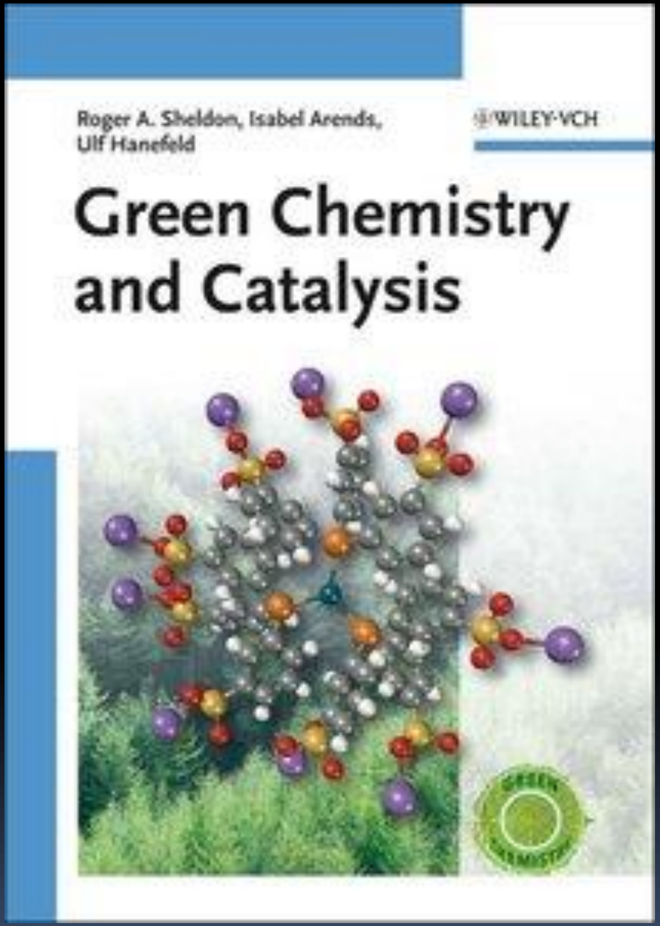




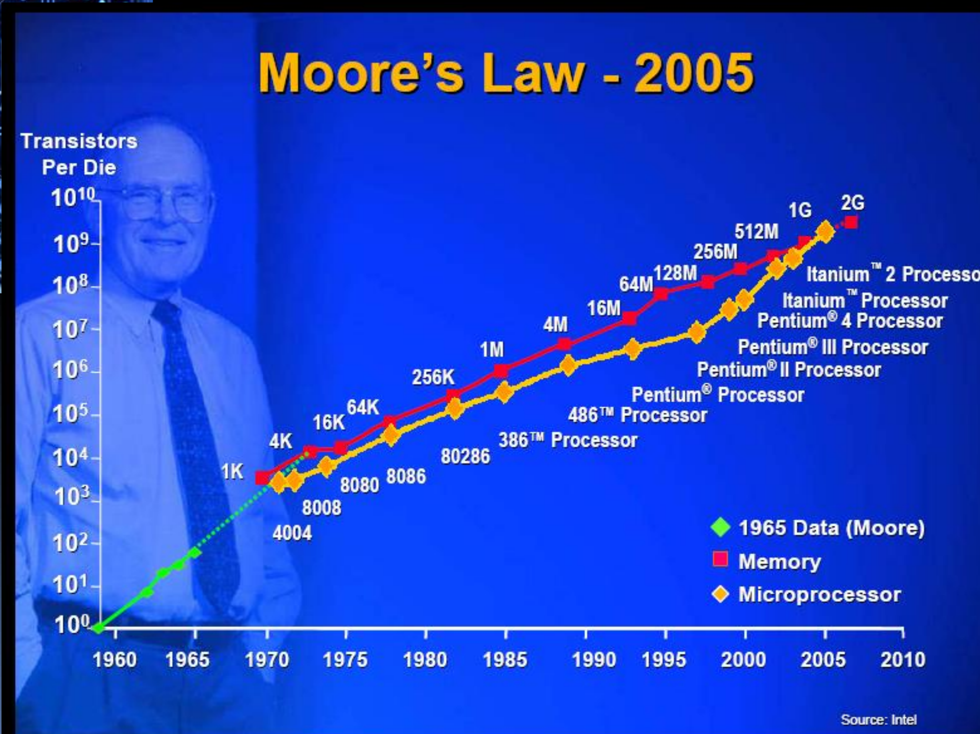


Research Hot Spots – Catalysis





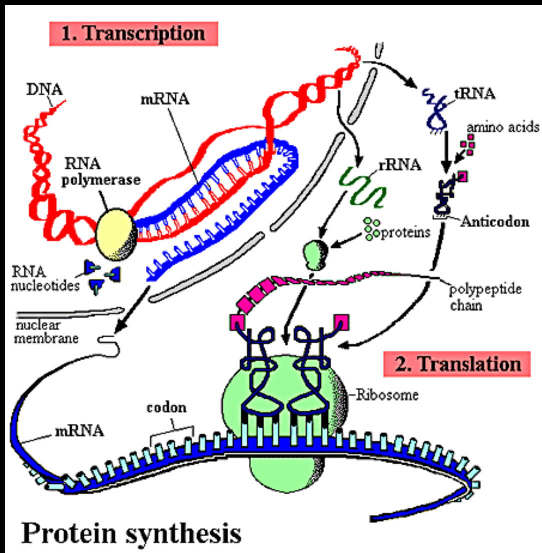
Research Hot Spots – Electronics

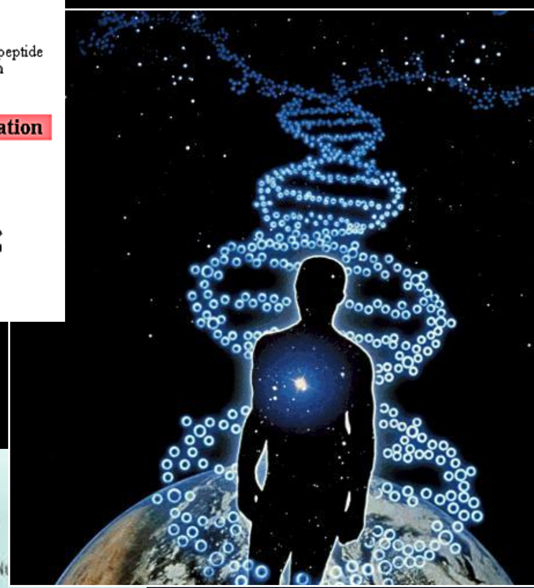


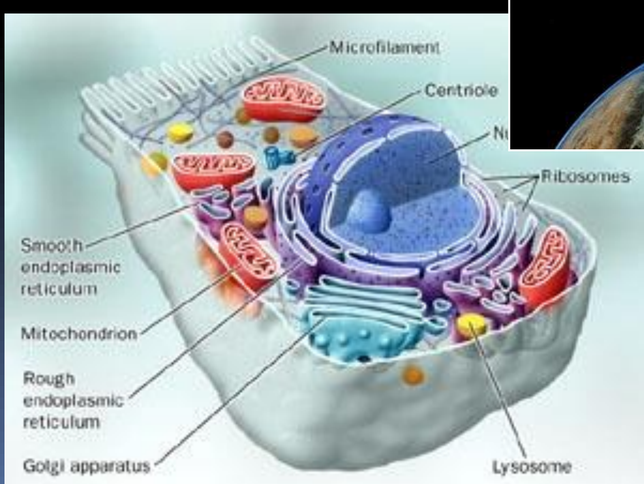
Moore's Law (Intel, 1965):

—— In every 18~24 months, the transistor size will shrink in half and the density will double.

Research Hot Spots – Bio & Medicine

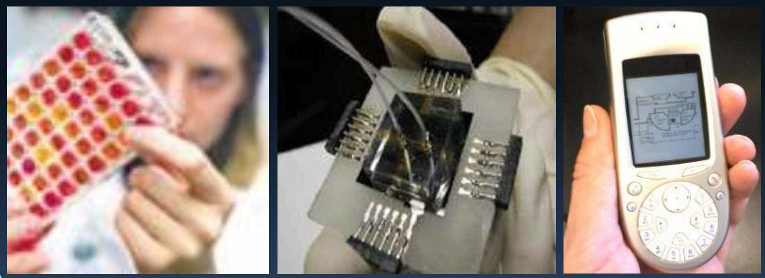




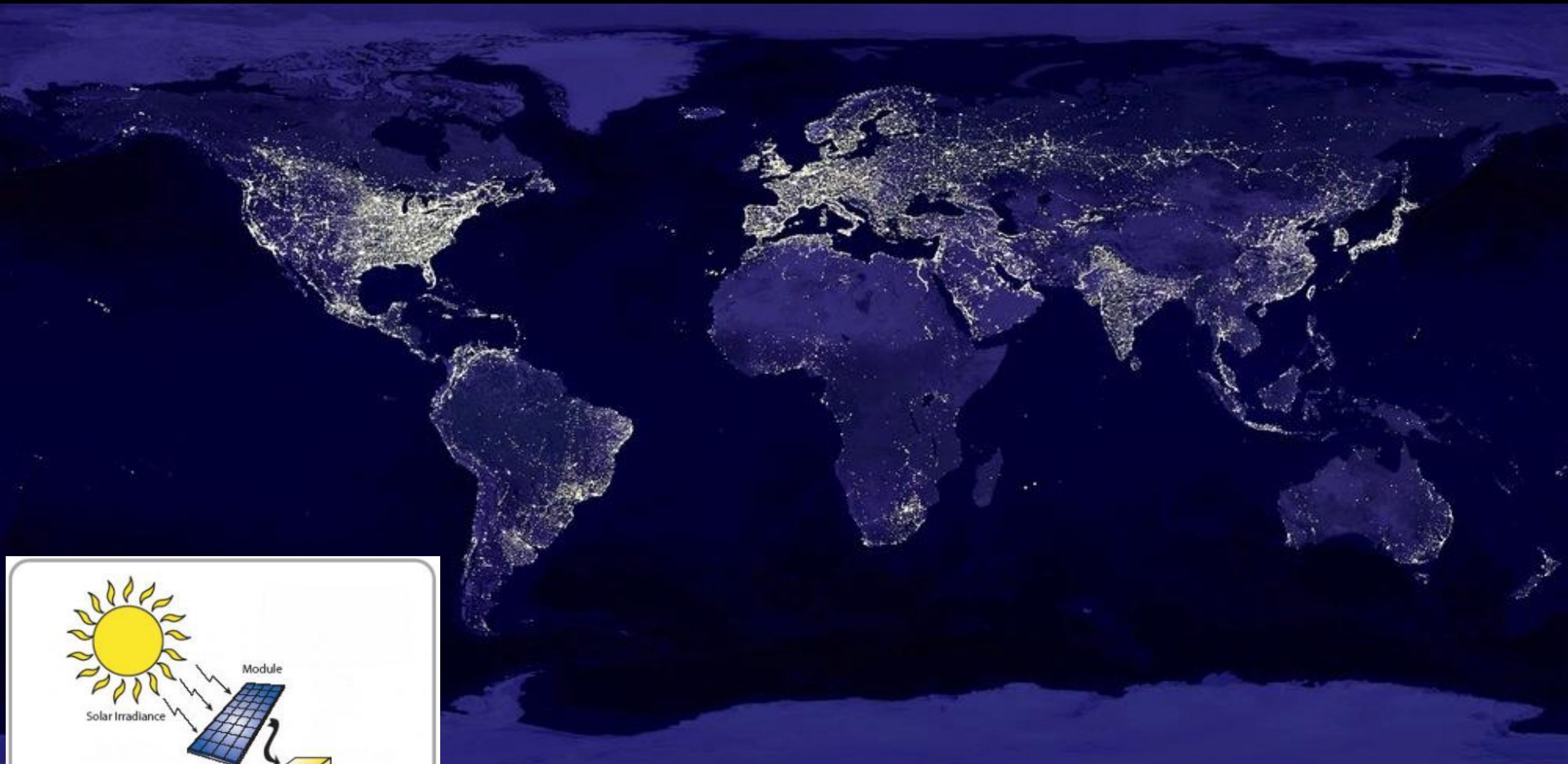


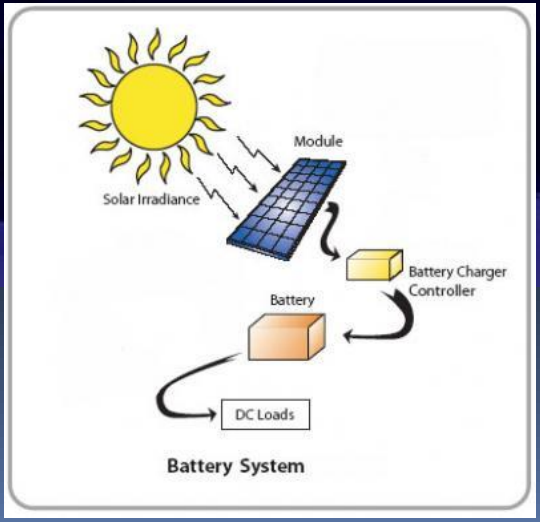
Early and fast diagnosis

From benchside to bedside



Research Hot Spots – Renewable Energy

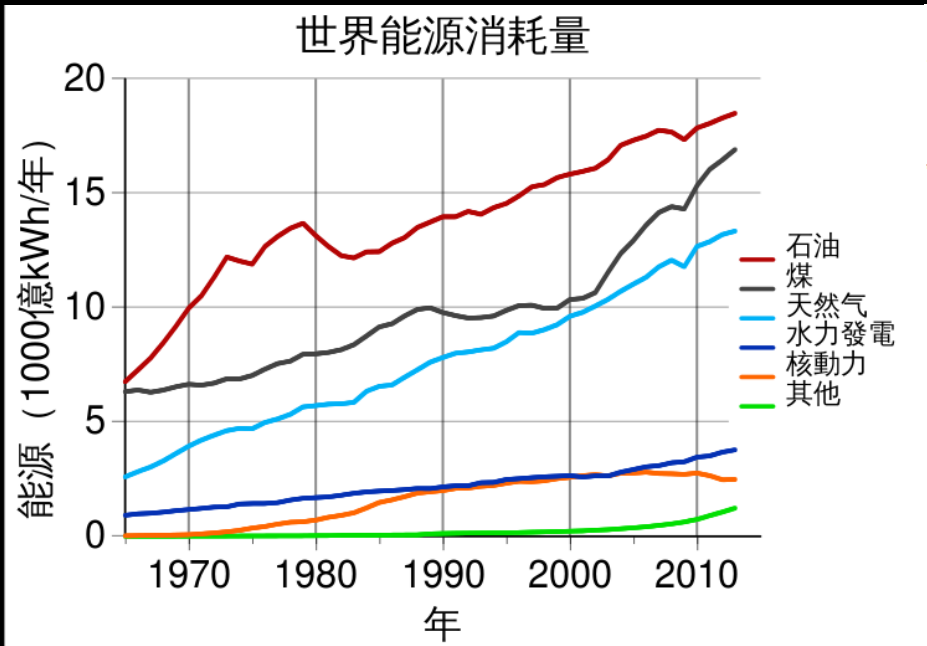


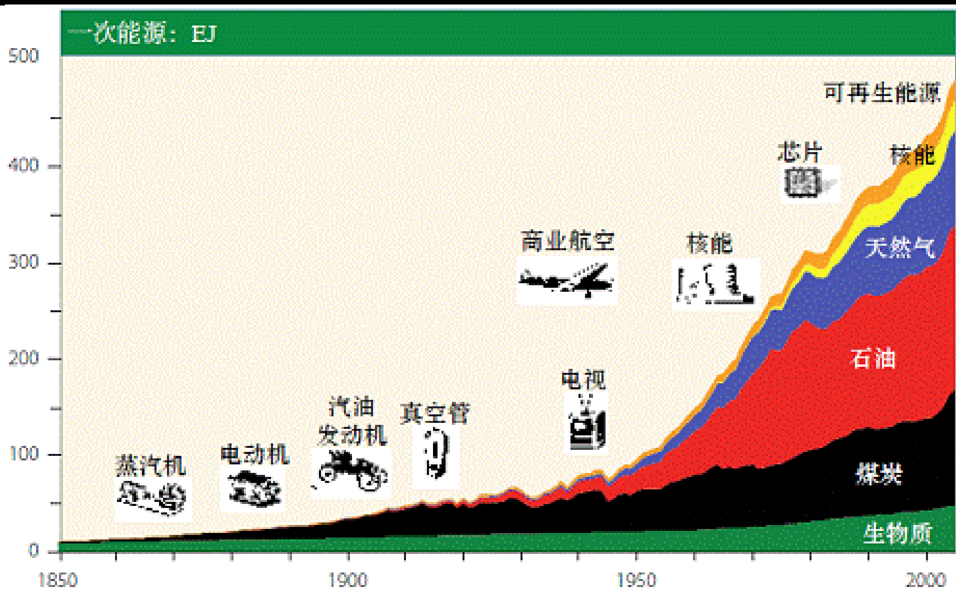


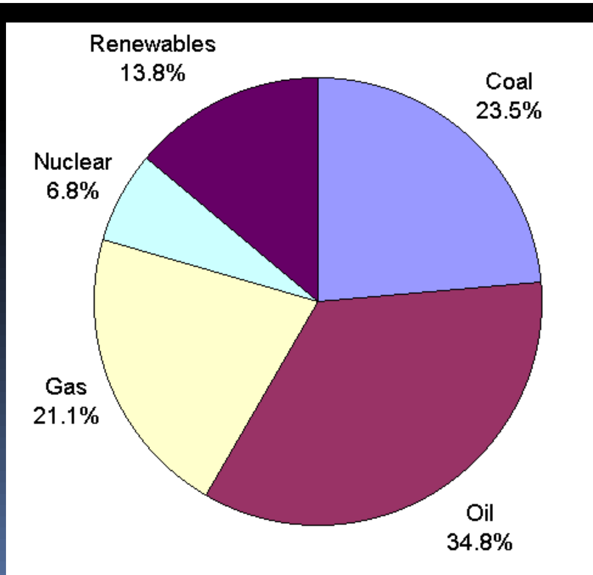
Global Energy Requirement: 15-20 × 10^{12} Watt (Terawatt); comparing to a nuclear power plant is ~ 10^{6} - 10^{7} Watt.

Annual global energy consumption: 5-6 × 10^{12} kW-h

Research Hot Spots – Renewable Energy



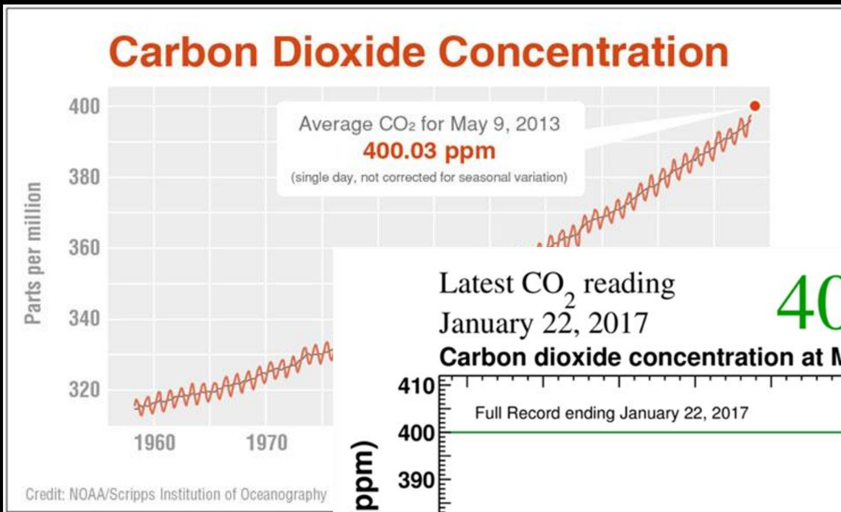


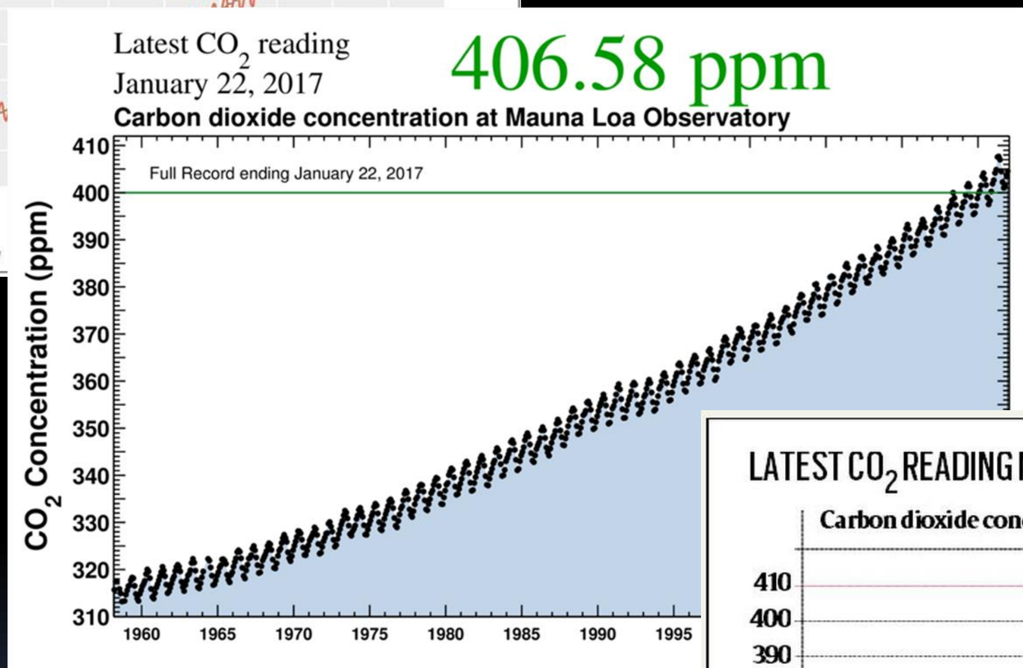


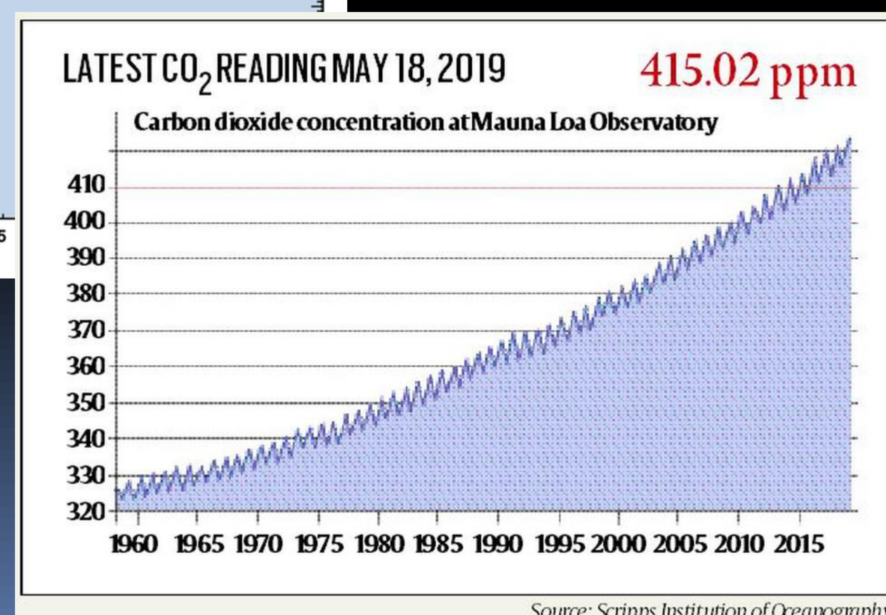
Fossil fuel (oil, coal, natural gas, shale gale) > 80% global energy consumption

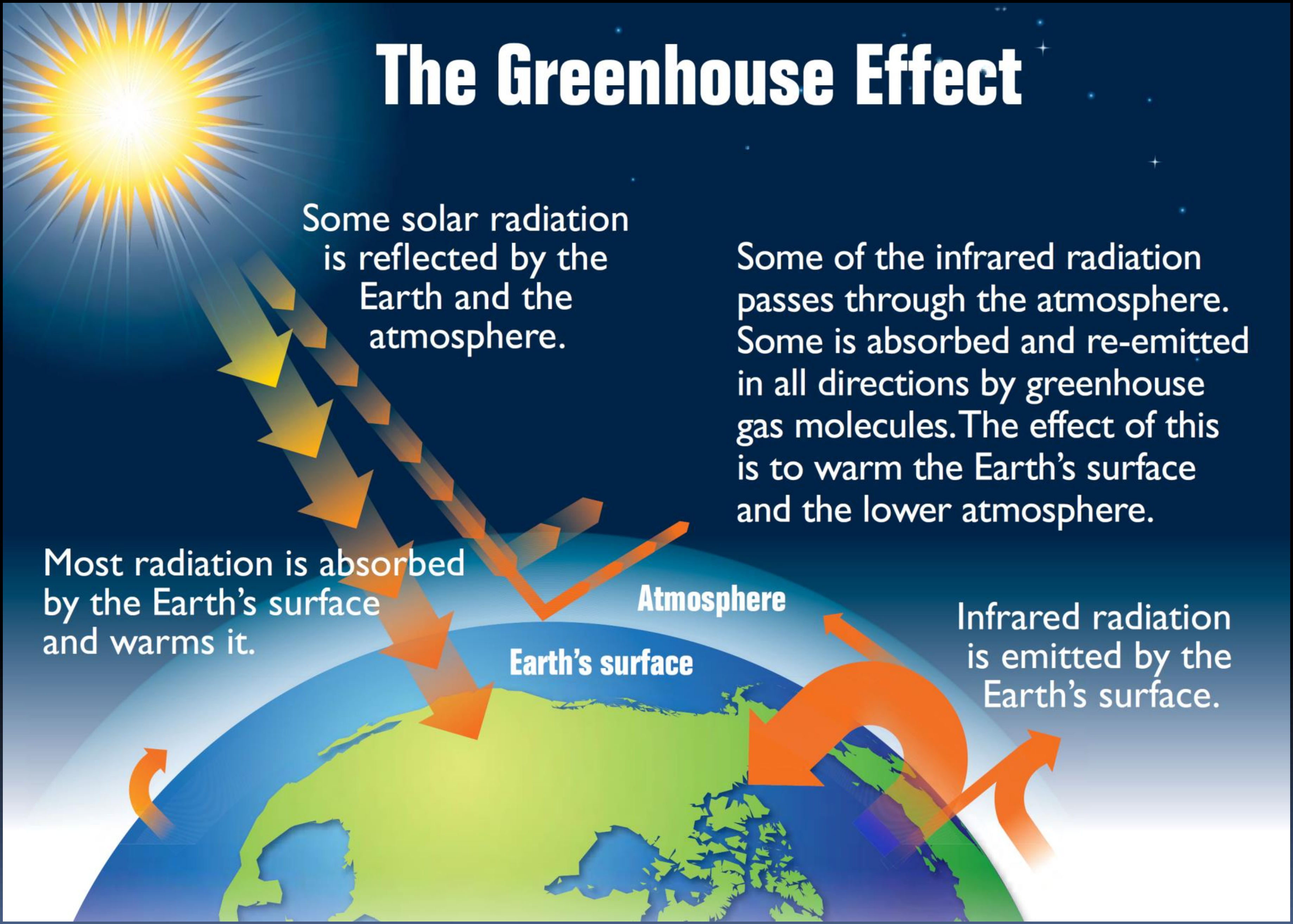
In the past 20 yrs, Renewable energy is taking more percentile each yr.

Pollution: CO_2 Emission








The Greenhouse Effect
Some solar radiation is reflected by the Earth and the atmosphere.
Some of the infrared radiation passes through the atmosphere. Some is absorbed and re-emitted in all directions by greenhouse gas molecules. The effect of this is to warm the Earth's surface and the lower atmosphere.
Most radiation is absorbed by the Earth's surface and warms it.
Atmosphere
Earth's surface
Infrared radiation is emitted by the Earth's surface.

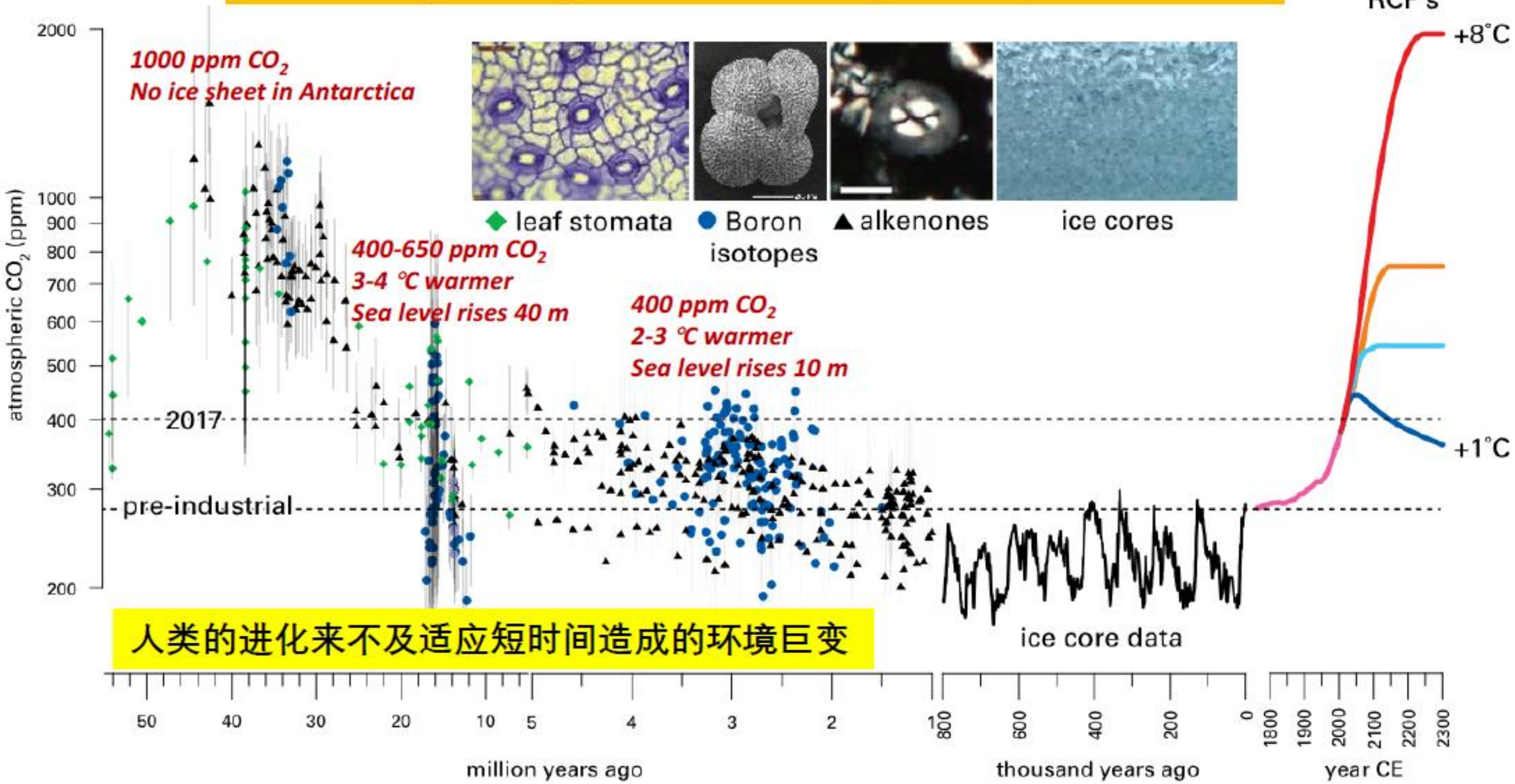
WORLD METEOROLOGICAL ORGANIZATION | GLOBAL ATMOSPHERE WATCH

WMO GREENHOUSE GAS BULLETIN

The State of Greenhouse Gases in the Atmosphere Based on Global Observations through 2016

No. 13 | 30 October 2017

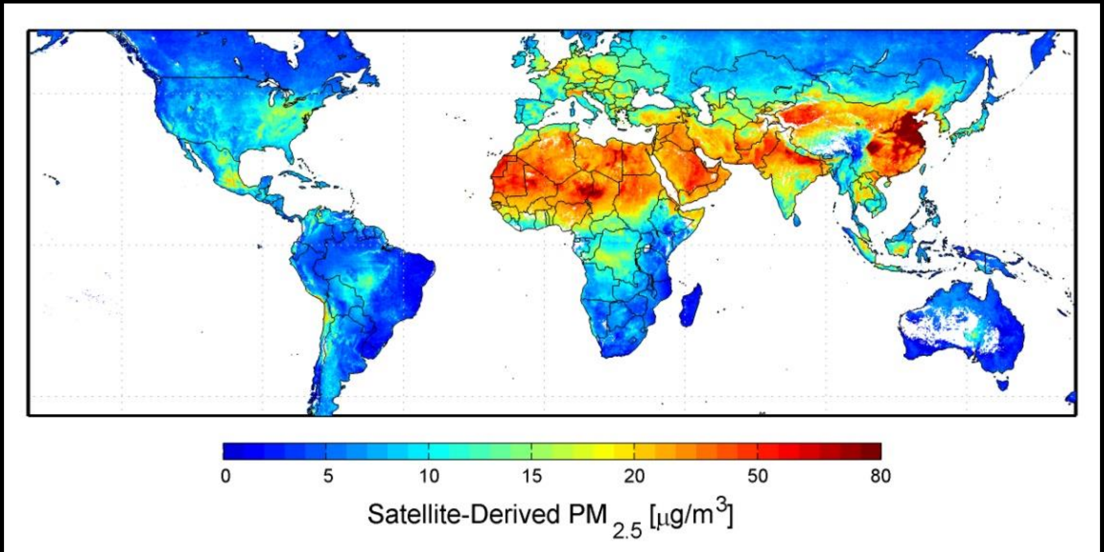
How earth system Reponses to the atmospheric CO_2 concentration?

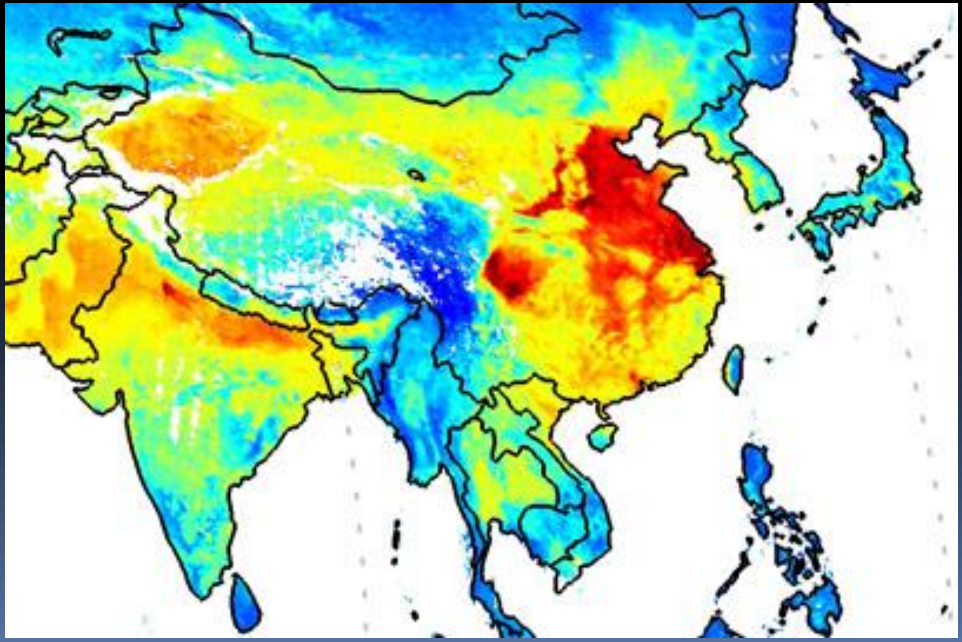


人类的进化来不及适应短时间造成的环境巨变

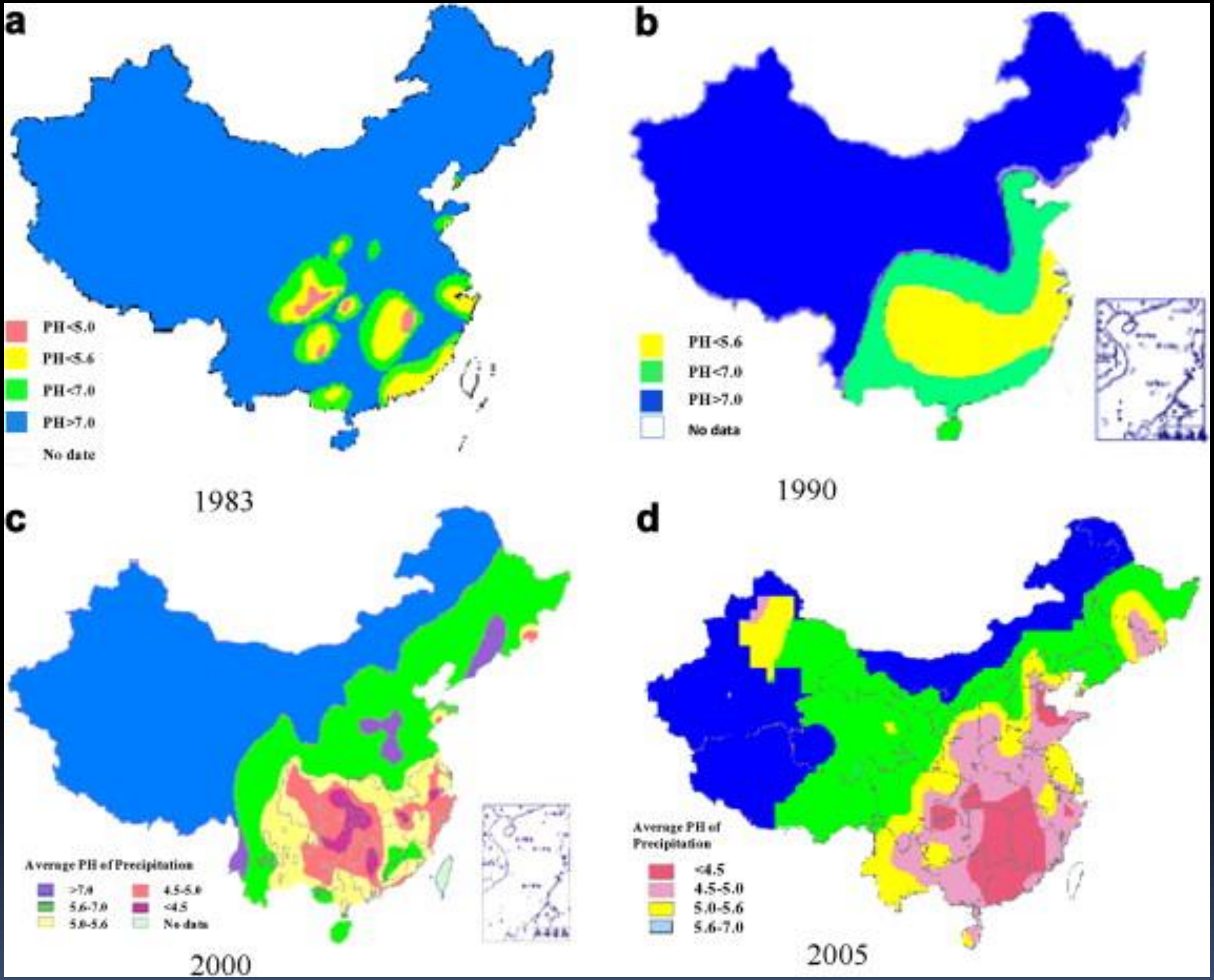
WMO Greenhouse Gas Bulletin, Oct. 2017

Pollution: Particles (PM 2.5, PM 10…)





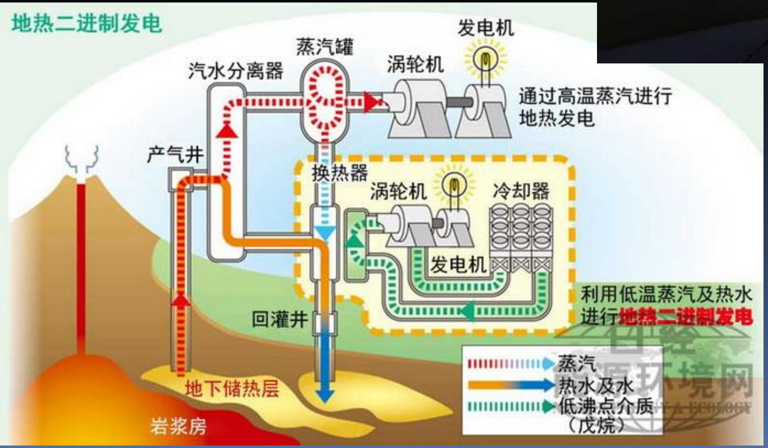
Pollution: Acidic Rain



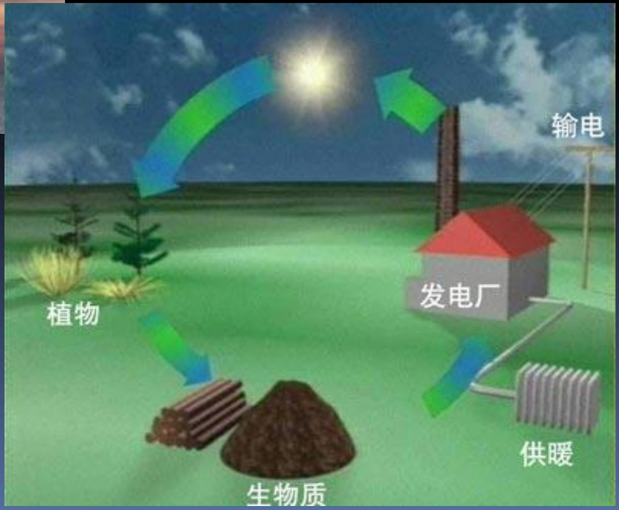
Acidifying of soil & water, due to combustion of N, S, Cl in fossil fuels

Renewable (Clean, Alternative) Energy

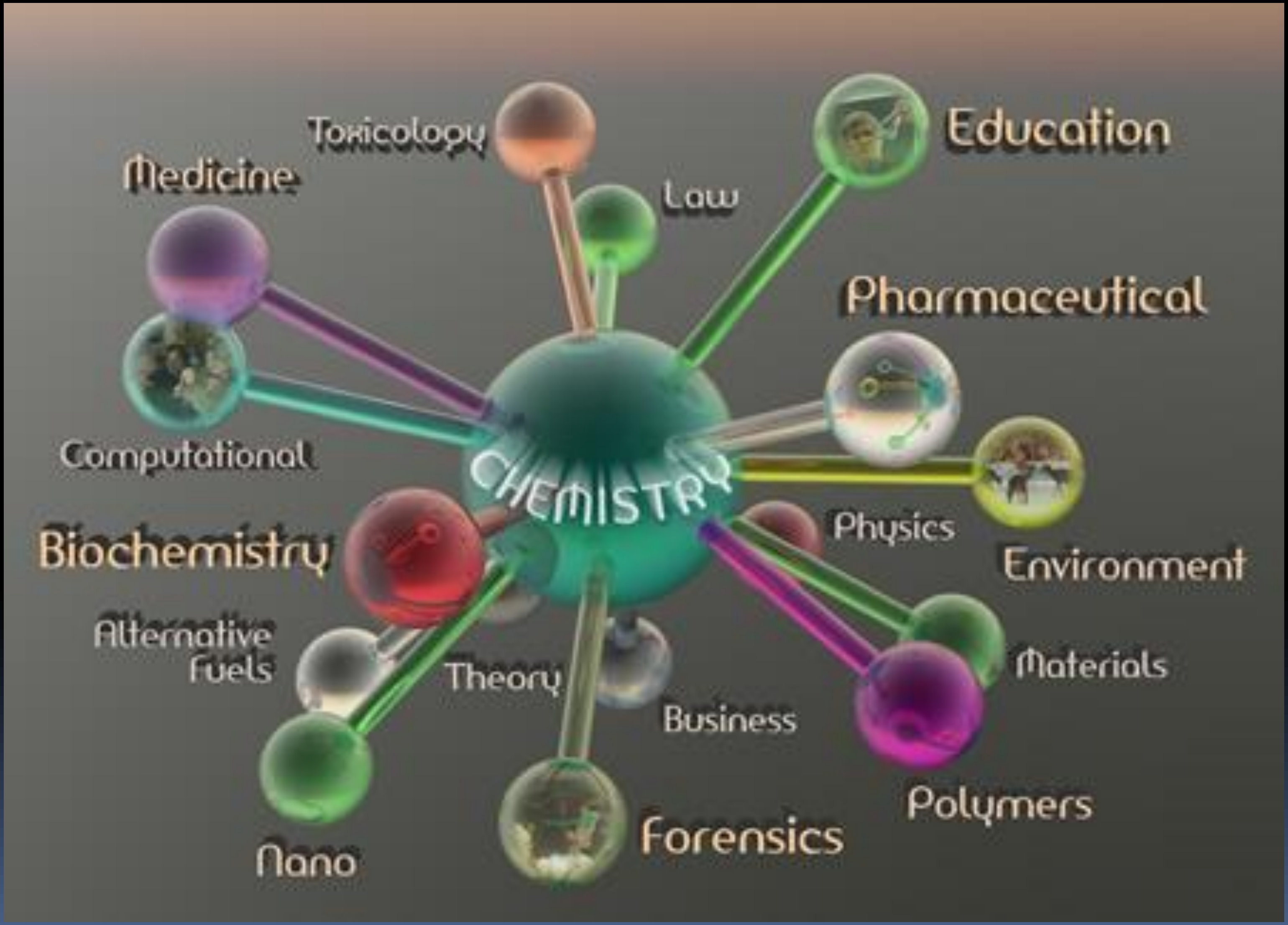
Geothermal



Biofuel



Importance of Chemistry



Elements, Compounds, & Mixtures

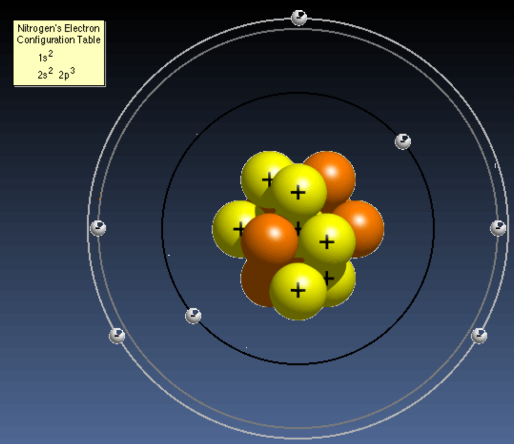
- Element
  - substance that cannot be decomposed into simpler substances.
  - e.g. H_2, O_2, N_2, C, Si, Au, Fe, …
- Compound
  - substance that is composed of two or more elements.
  - e.g. H_2O, CO_2, NH_3, CH_3CH_2OH, …

Elements, Compounds, & Mixtures

- Mixture
  - a sample of matter that is composed of two or more substances.
  - e.g. aqueous solution = solvent (water) + solute
  - Homogeneous mixture (one phase) vs. Heterogeneous mixture (more than 1 phase)

Atoms, Molecules, and Ions

- Atom
  - smallest particle of an element that takes part in chemical reactions. (e.g. H, C, N, O …)
  - composed of a positively charged nucleus and negatively charged electrons.

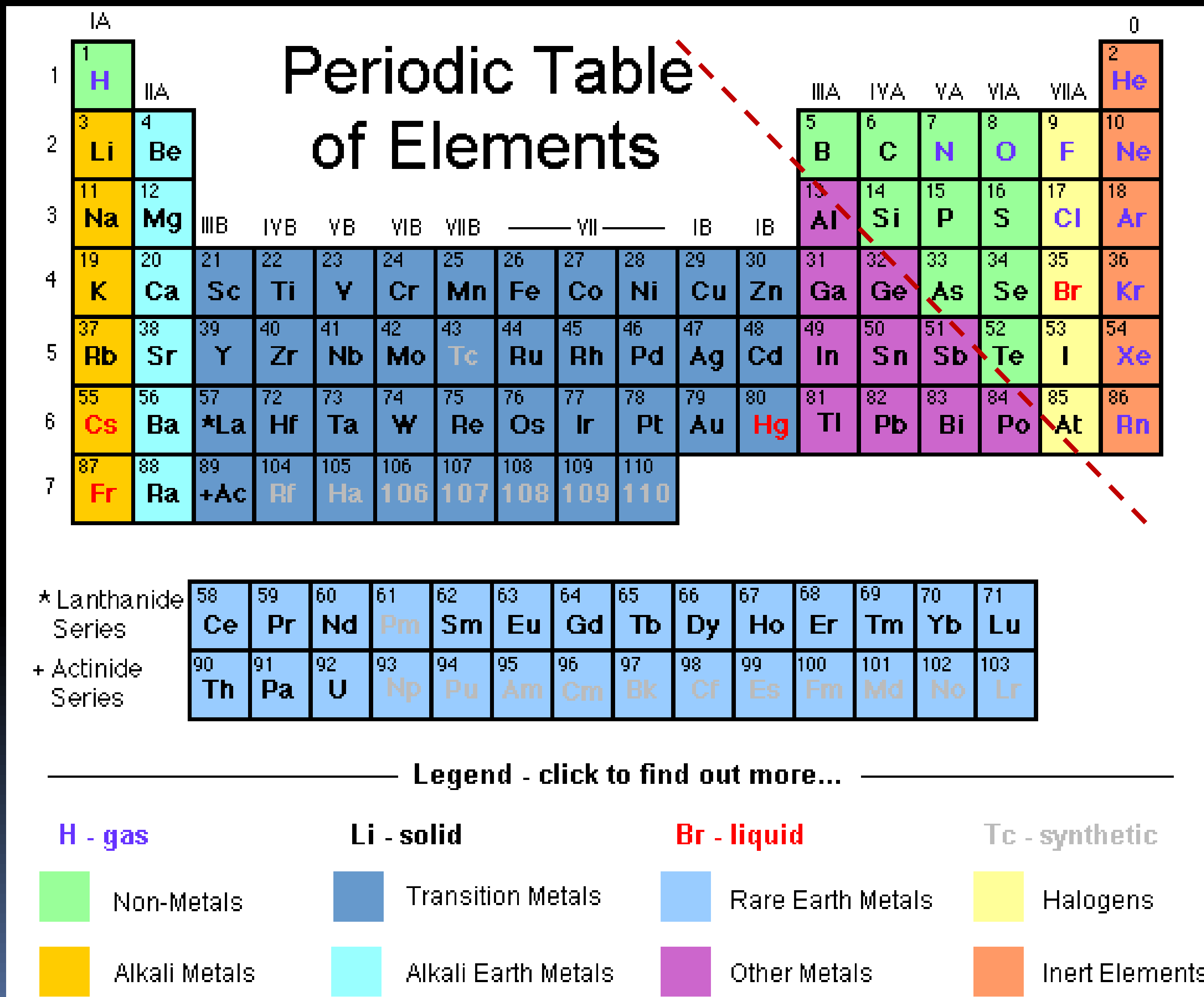


Atoms, Molecules, and Ions

- Molecule
  - the smallest particle of a specific element or compound that retains the chemical properties of that element or compound. (e.g. H_2, O_2, CO_2 …)

- Ion
  - an atom or molecule or chemical group that has lost or gained one or more electrons. (e.g. H^+, OH^-)

Periodic Table



Physical & Chemical Change

- Physical Change
  - does not involve changing any substances into any other substances

- Chemical Change (Chemical Reaction)
  - involves changing some substances into new substances.

Measurement and Units

- SI Units
- Prefix of units
- Unit conversion

TABLE 1.4 SI Base Units

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

[a] The abbreviation sec is frequently used.

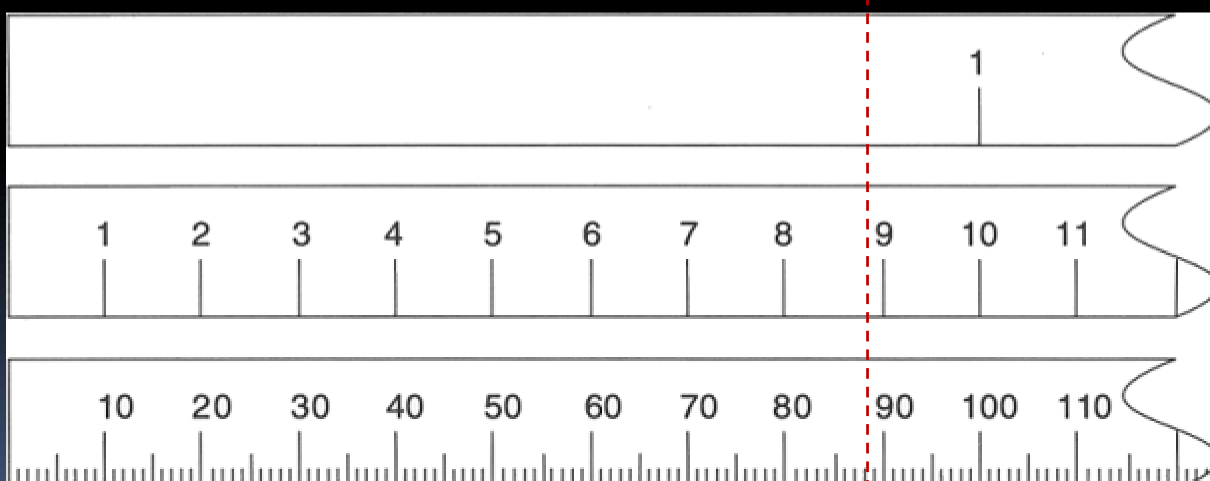
TABLE 1.5 Selected Prefixes Used in the Metric System

Prefix	Abbreviation	Meaning	Example
Giga	G	10^9	1 gigameter (Gm) $= 1 \times 10^9$ m
Mega	M	10^6	1 megameter (Mm) $= 1 \times 10^6$ m
Kilo	k	10^3	1 kilometer (km) $= 1 \times 10^3$ m
Deci	d	10^{-1}	1 decimeter (dm) = 0.1 m
Centi	c	10^{-2}	1 centimeter (cm) = 0.01 m
Milli	m	10^{-3}	1 millimeter (mm) = 0.001 m
Micro	μ[a]	10^{-6}	1 micrometer (μm) $= 1 \times 10^{-6}$ m
Nano	n	10^{-9}	1 nanometer (nm) $= 1 \times 10^{-9}$ m
Pico	p	10^{-12}	1 picometer (pm) $= 1 \times 10^{-12}$ m
Femto	f	10^{-15}	1 femtometer (fm) $= 1 \times 10^{-15}$ m

[a] This is the Greek letter mu (pronounced "mew").

Uncertainty of Measurement

What is the length of this green box?



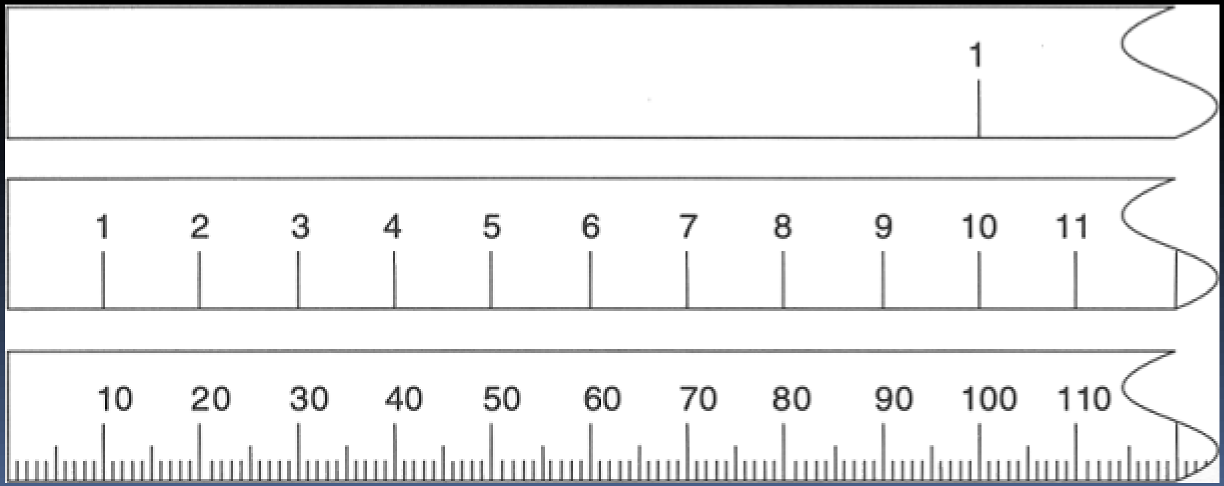
0.9 dm

8.8 cm

88.5 mm

Scientific Notation

- Definition:
  - a method of writing for displaying real numbers as a decimal number between 1 and 10, followed by an integer power of 10, (or as in a form of E).



0.9 dm = 9×10^{-2} m
(9E-2 m)

8.8 cm = 8.8×10^{-2} m
(8.8E-2 m)

88.5 mm = 8.85×10^{-2} m
(8.85 E-2 m)

Significant Figures

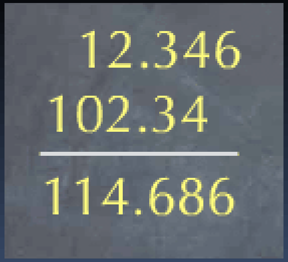
- Number of significant figures

  0.9 dm = 9 x 10^{-2} m → **1 digit**

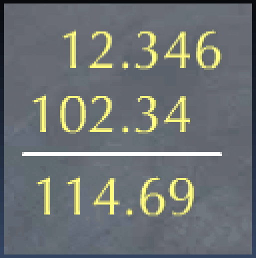
  8.8 cm = 8.8 x 10^{-2} m → **2 digits**

  88.5 mm = 8.85 x 10^{-2} m → **3 digits**

- Calculation of significant figures



Wrong



Correct

Extensive Property & Intensive Property

- Extensive Property
  - Properties that depend on the quantity of samples measured.
  - e.g. mass, volume, energy
- Intensive Property
  - Properties that are independent on the quantity of samples measured.
  - e.g. temperature, time, density, pressure

Amount of Substance

- Avogadro's number (N_A)
  - $N_A = 6.02 \times 10^{23}$
- Mole:
  - One mole is composed of Avogadro numbers of "elementary entities" (usually atoms or molecules).
- Quantity correspondence in a chemical reaction
  - e.g. $N_2 + 3\,H_2 \rightarrow 2\,NH_3$, $H_2 + \frac{1}{2}\,O_2 \rightarrow H_2O$

A few important Properties & Units

- Density (kg/m^3) = Mass / Volume
  - Q: 1 g/cm^3 = ?? kg/m^3
- Pressure (Pa) = Force / Area
  - 1 atm (atmosphere) = 1.01 x 10^5 Pa = 760 mmHg = 760 Torr
- Temperature (K)
  - 0 ^oC = 273.15 K; x ^oC = x + 273.15 K
- Energy (J)
  - 1 cal (calorie) = 4.18 J

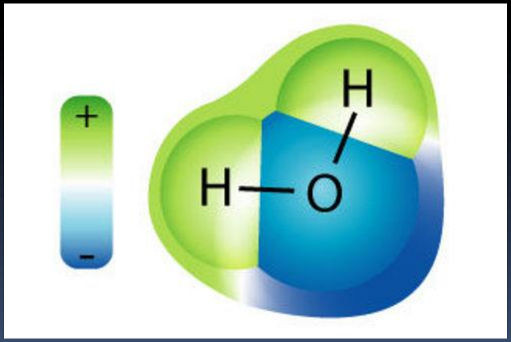
A few important Properties & Units

- Molarity (mol/L or M) = Amount of substance of solute / Volume of solution

- Heat Capacity (J/mol) = Energy / Amount of substance

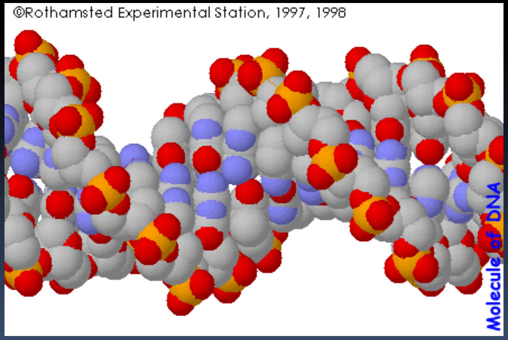
Atomic Mass & Molecular Mass

- Atomic weight (Atomic mass)
  - the mass of an atom of a chemical element expressed in atomic mass units
- Molecular weight (Molecular mass)
  - sum of the atomic masses of all atoms of a molecule



a water molecule

(MW = 18)



a DNA molecule

(MW = a few thousand even million)

Stoichiometry

- Law of Conservation of Matter
  - Matter is neither created nor destroyed, but is combined and rearranged in different ways.
- Stoichiometry
  - the relation between the quantities of substances that take part in a reaction or form a compound.
  - e.g. $2\ H_2\ (g) + O_2\ (g) \rightarrow 2\ H_2O\ (l)$

Balancing the Chemical Equation

- Method
  - 1. Begin with the compound that has the most atoms or the most kinds of atoms, and use one of these atoms as a starting point;
  - 2. Balance elements that appear only once on each side of the arrow first;
  - 3. Balance the remaining elements;
  - 4. Make all the coefficient as integers.

Balancing the Chemical Equation

- Practices:
  - Methyl alcohol burning in air:

    __ CH_4O + __ O_2 → __ CO_2 + __ H_2O

  - Industry synthesis of nitric oxide:

    __ NH_3 + __ O_2 → __ NO + __ H_2O

  - Semiconductor/computer chip etching process:

    __ SiO_2 + __ HF → __ SiF_4 + __ H_2O

Limiting Reactant

- Limiting reactant (reagent)
  - the chemical that determines how far the reaction will go before the chemical in question gets "used up", causing the reaction to stop.
  - Examples

Limiting Reactant

- Practices:
  - (1) What is the volume of O_2 (g) is required to fully burn out 6.0 g graphite (carbon) powder? (Assuming 1 mole of O_2 gas takes up 22.4 liter.)
  - (2) A mixture of 3.0 g H_2 (g) and 32.0 g O_2 (g) is made to react. How much reactant is left over? How many grams of water can be formed?

Empirical Formula

- Finding the Empirical Formula from mass percentage:
  - (1) Converting the mass percentage into mole percentage;
  - (2) Converting the ratio into integers by dividing each subscript by the smallest subscript number.
  - Example: (book Pg. 90, 3.11)

Example

- Q: The composition of a compound is 36.4% Mn, 21.2% S, and 42.4% O. (mass percents). What is the empirical formula?

- Q: The composition of a compound is 27.6% Fe, 24.2% S, and 48.2% O. What is the empirical formula of this compound?

- Atomic mass: Mn 54.9, S 32.1, O 16.1, Fe 55.8

- Solution: Assuming 100 g, $Mn_xS_yO_z$:

  then, it has 36.4 g Mn, 21.2 g S, and 42.4 g O;

  Mn: 36.4 g / 54.9 g/mol = 0.663 mol Mn;

  S: 21.2 g / 32.1 g/mol = 0.660 mol S;

  O: 42.4 g / 16.0 g/mol = 2.65 mol O.

  therefore: divide the smallest number (0.660),

  the formula is: $MnSO_4$.