CHEM1300 Principles of General Chemistry

Semester B 2021/22

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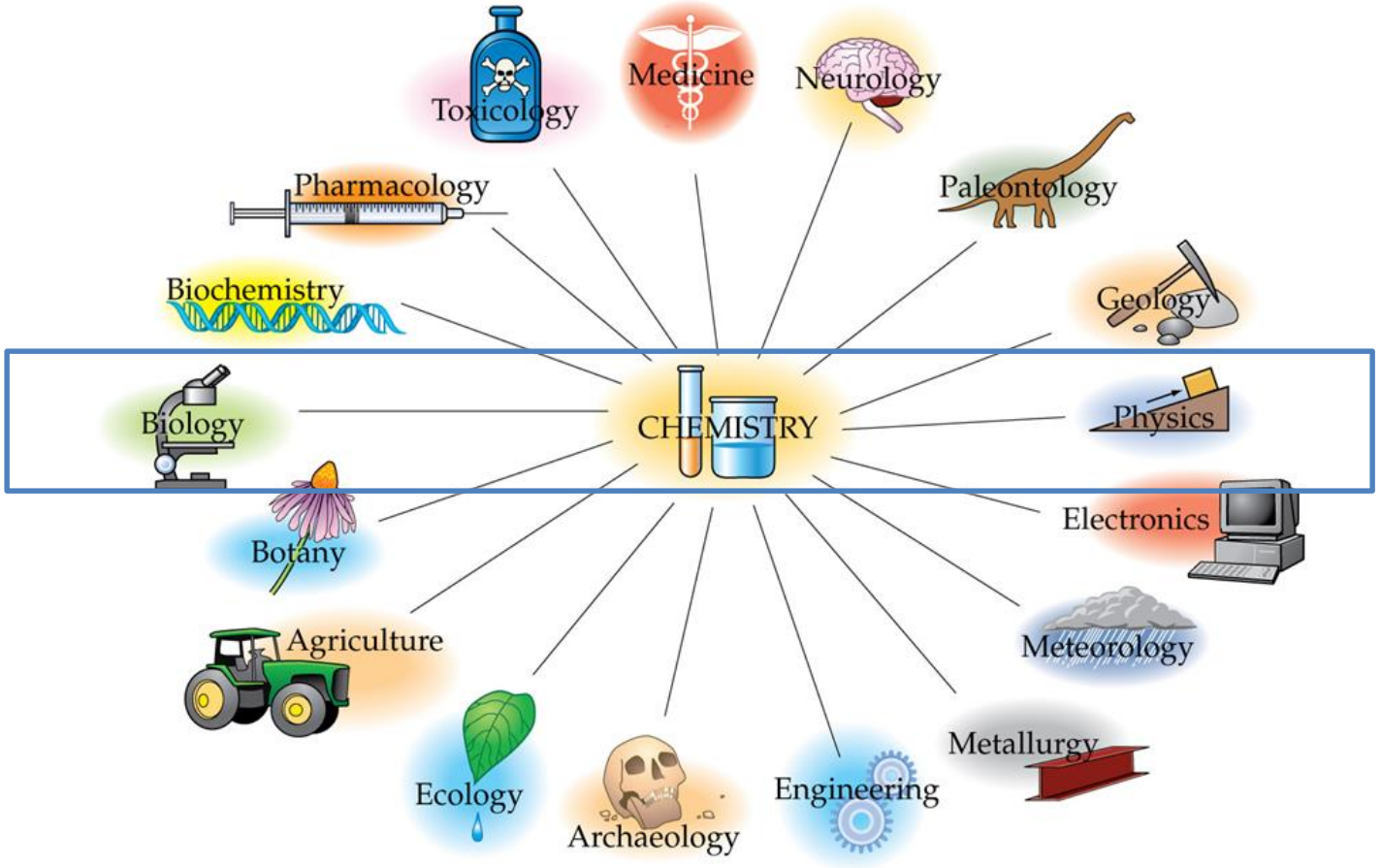
Fridays, 09:00 – 10:50

BOC LT401

Chemistry is unique among all the sciences because it is the only discipline that routinely and on a daily basis **creates entirely new forms of matter**.



Because it plays a vital role in shaping so many aspects of modern life, ***serious study of chemistry at a fundamental level should be part of every well-educated person's university experience.***

Recommended Reading

"**Chemistry: The Central Science**", Global Edition, 14th Ed, Brown / LeMay,Jr. / Bursten / Murphy / Woodward / Stoltzfus, Pearson (ISBN 9781292057712)

- **Lectures 1–2 / Tutorial 1:**
  Dr. Andy Siu (AS)
  G6622, YEUNG

  Chapter 2: Atoms, Molecules, and Ions
  Chapter 6: Electronic Structure of Atoms
  Chapter 8: Basic Concepts of Chemical Bonding

- **Lectures 3–4 / Tutorial 2:**
  Dr. Will YK Peng (YKP)
  B6704, YEUNG

  Chapter 7: Periodic Properties of the Elements
  Chapter 8: Basic Concepts of Chemical Bonding
  Chapter 9: Molecular Geometries and Bonding Theories

- **Lectures 5–8 / Tutorial 3:**
  Dr. Peggy PK Lo (PLo)
  B6523, YEUNG

  Chapter 5: Thermochemistry
  Chapter 10: Gases
  Chapter 14: Chemical Kinetics
  Chapter 15: Chemical Equilibrium

- **Lectures 9–12 / Tutorial 4:**
  Prof. Michael CW Chan (MC)
  G6615, YEUNG

  Chapter 11: Liquids and Intermolecular Forces
  Chapter 13: Properties of Solutions
  Chapter 24: Chemistry of Life: Organic and Biological Chemistry

Class Schedule of CHEM1300 Semester B 2021/22

CHEM1300 Principles of General Chemistry		Lecture	Tutorial		Laboratory	
		C01	T01	T02	L01	L02
Week	Period (Sun-Sat)	F 0900-1050 BOC LT401	W 1000-1150 YEUNG LT-3	W 1500-1650 YEUNG LT-4	W 0900-1250 YEUNG P4813	W 1400-1750 YEUNG P4813
Teaching Staff		AS / YKP / PLo / MC (Lecture + Tutorial)			MC	PLo
1	10/1 - 15/1	Lec 1 (AS)	Tutorials and lab sessions will begin in Week 3			
2	16/1 - 22/1	Lec 2 (AS)				
3	23/1 - 5/2 31/1-6/2(M-S) Lunar New Year Break	Lec 3 (YKP)	Tut 1 (AS)	Tut 1 (AS)		
4	6/2 - 12/2	Lec 4 (YKP)			Lab 1 Safety Briefing	Lab 1 Safety Briefing
5	13/2 - 19/2	Lec 5 (PLo)	Tut 2 (YKP)	Tut 2 (YKP)		
6	20/2 - 26/2	Lec 6 (PLo)				
7	27/2 - 5/3	Lec 7 (PLo)			Lab 2 (Expt 1)	Lab 2 (Expt 1)
8	6/3 - 12/3	Lec 8 (PLo)	Tut 3 (PLo)	Tut 3 (PLo)		
9	13/3 - 19/3	Lec 9 (MC)				
10	20/3 - 26/3	Lec 10 (MC)			Lab 3 (Expt 2)	Lab 3 (Expt 2)
11	27/3 - 2/4	Lec 11 (MC)			Lab 4 (Expt 3)	Lab 4 (Expt 3)
12	3/4 - 9/4 5/4(T) Ching Ming Festival	Lec 12 (MC)	Tut 4 (MC)	Tut 4 (MC)		
13	10/4 - 23/4 15-21/4(F-R) Easter Break	Holiday				

Assessment

- **30% in Coursework**
  - Assignments (via Canvas)
  - Laboratory performance and lab quizzes

- **70% in Final Examination (2 hours)**
  - 90 Multiple-choice questions

- ***Minimum Passing Requirement***

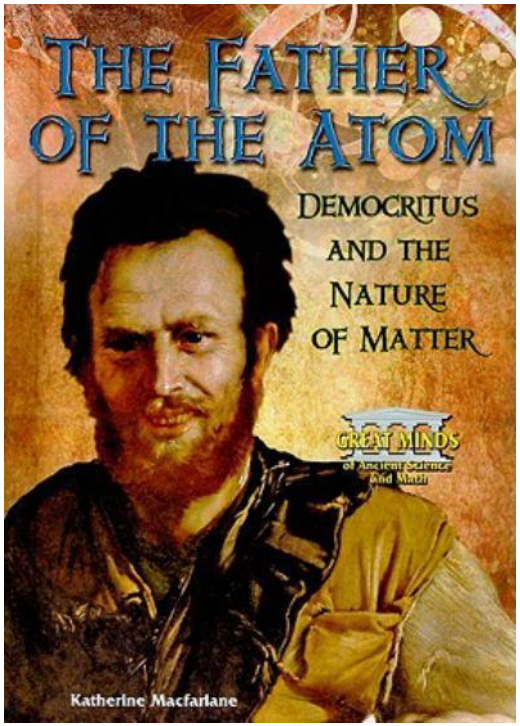
  A minimum of 40% in both coursework and examination components

  COURSE WORK AND EXAMINATION ARE BOTH IMPORTANT!

Atoms

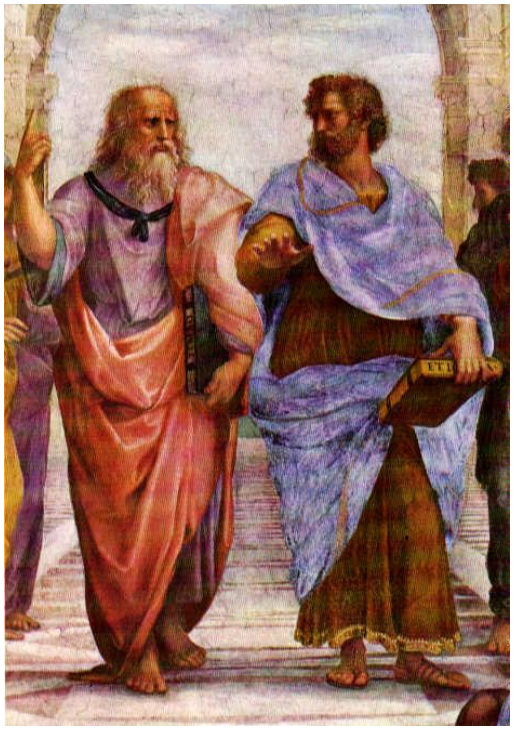
Democritus
(460 – 370 BC)

Matters made up of indivisible particles, called atomos.



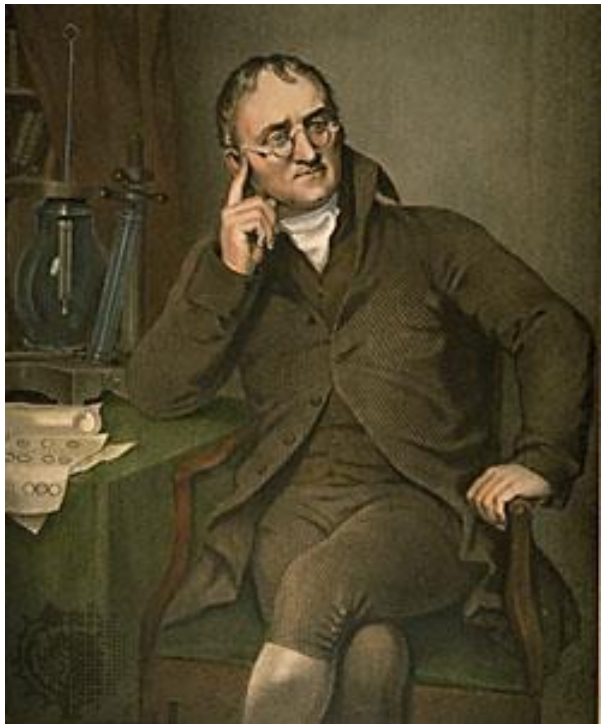
Plato (427 – 347 BC)
Aristotle (384 – 322 BC)

There can be no indivisible particles
— *an idea that hindered the development of chemistry?!*



John Dalton
(1766 – 1844 AC)

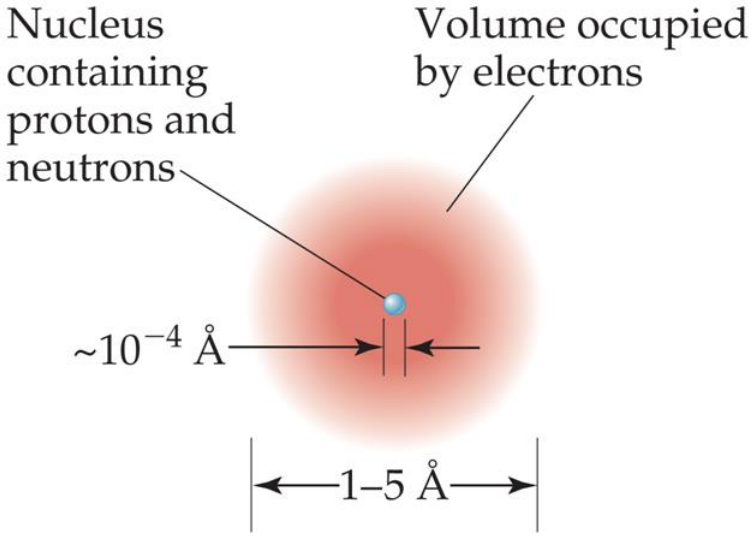
Matters consisted of tiny particles, called **atoms**.



A Simplified View of Atomic Structure / 1

- Later, scientists have realized that an atom is made up of smaller particles, including
  - ***protons* (positively charged)**
  - ***electrons* (negatively charged,**
  - ***neutrons* (electrically neutral),**

  from which ***ALL*** atoms are made.



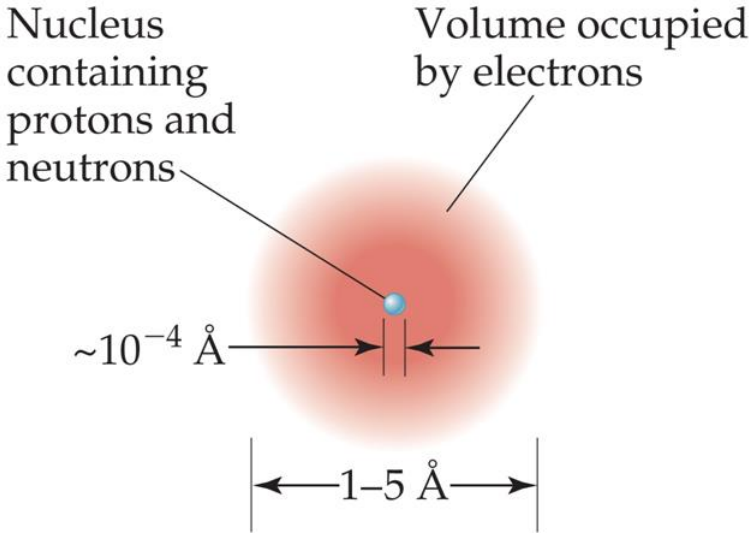
- Number of protons and electrons in a given atom are equal, so that the overall charge of the atom is zero (electrically neutral).

Table 2.1 Comparison of the Proton, Neutron, and Electron

Particle	Charge	Mass (amu)
Proton	Positive (1+)	1.0073
Neutron	None (neutral)	1.0087
Electron	Negative (1−)	5.486×10^{-4}

A Simplified View of Atomic Structure / 2

- Most of the **mass** of an atom resides in the **nucleus** (the central part of the atom), which consists of **protons** and **neutrons**.
- The masses of a proton and a neutron are almost equal.
- Most of the **volume** of an atom is due to the **electrons**, which move around the nucleus.



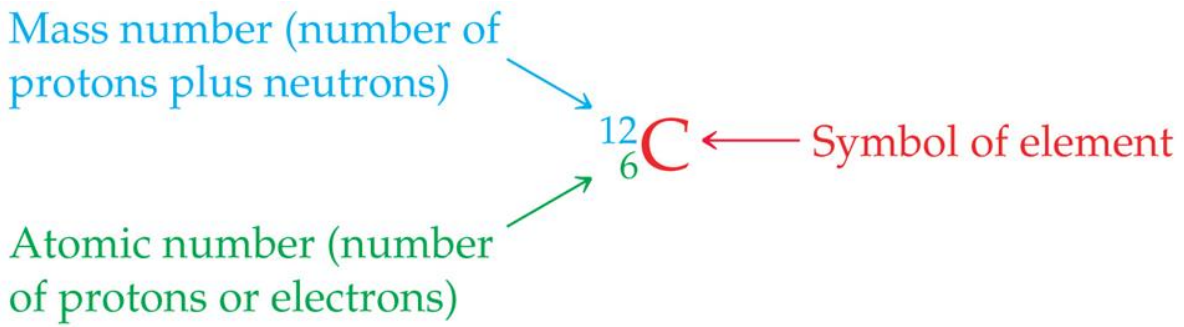
- The mass of an electron is so small that we can ignore it.

Table 2.1 Comparison of the Proton, Neutron, and Electron

Particle	Charge	Mass (amu)
Proton	Positive (1+)	1.0073
Neutron	None (neutral)	1.0087
Electron	Negative (1−)	5.486×10^{-4}

Elements

- An ***element*** is composed of only one type of atom.
- The atom of an element is represented by a ***chemical symbol***.



- Atoms of a given element must have the *same* atomic number (i.e. same number of protons), but can have *different* mass numbers (*i.e. different number of neutrons*), called as **isotopes** of that given element.

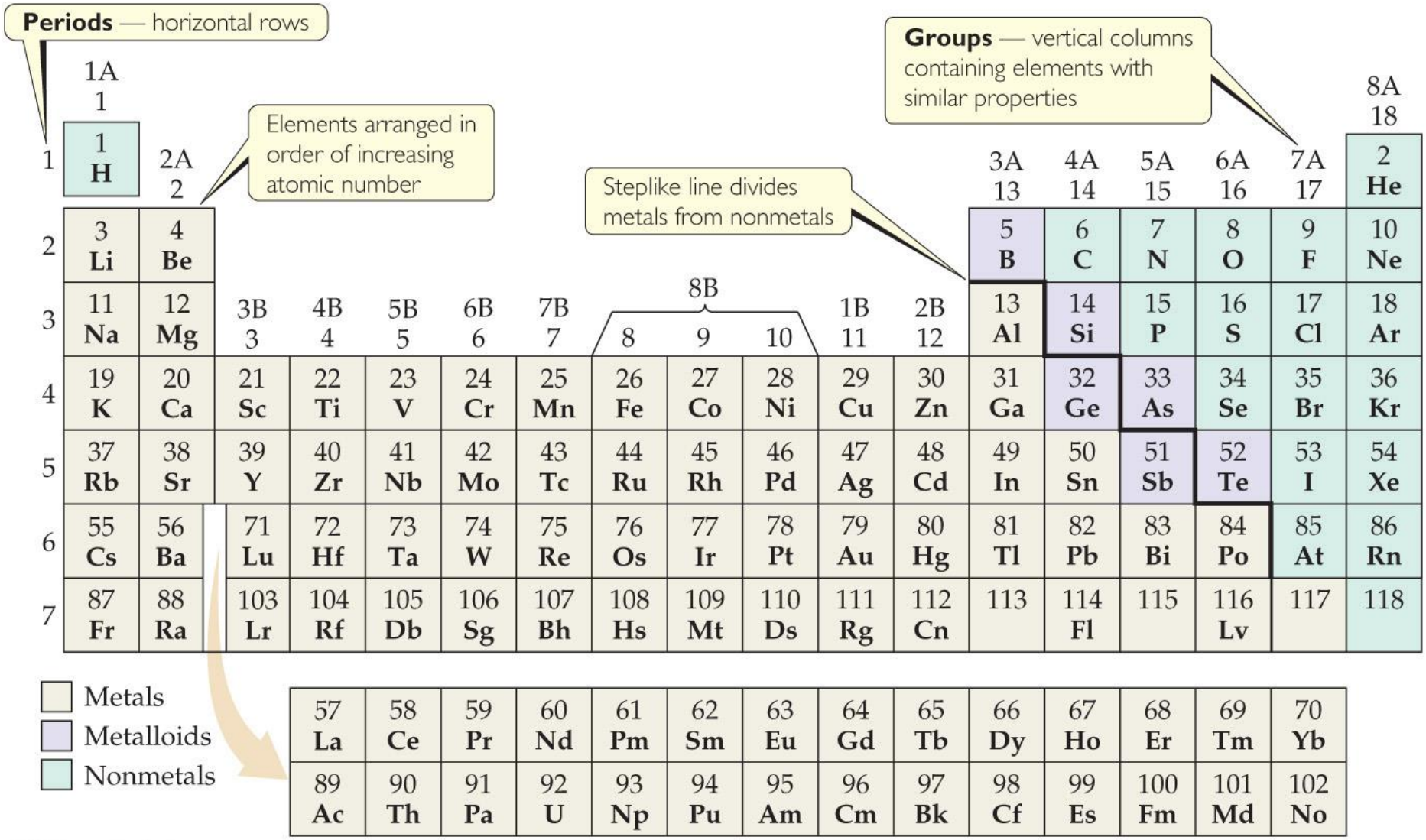
TABLE 2.2 • Some Isotopes of Carbon*

Symbol	Number of Protons	Number of Electrons	Number of Neutrons
^{11}C	6	6	5
^{12}C	6	6	6
^{13}C	6	6	7
^{14}C	6	6	8

*Almost 99% of the carbon found in nature is ^{12}C.

Periodic Table

— A systematic catalog of the elements



How Tiny Is an Atom?

The mass of a ^{12}C atom is defined as 12 atomic mass units (amu), which have been measured to be 1.992647×10^{-23} g / ^{12}C atom.

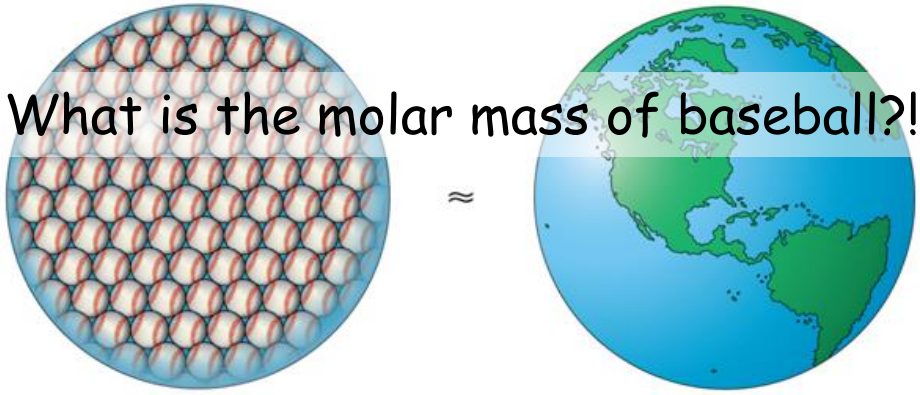
$$12 \text{ g of a pure carbon-12 sample} = \frac{12 g}{1.992647 \times 10^{-23} g / {}^{12}\text{C atom}}$$

$$= 6.02214 \times 10^{23} {}^{12}\text{C atoms (also defined as 1 mole of } {}^{12}\text{C atoms)}$$

A **mole (mol)** is defined as the amount of a substance that contains **6.02214×10^{23}** particles (**Avogadro's Number**).

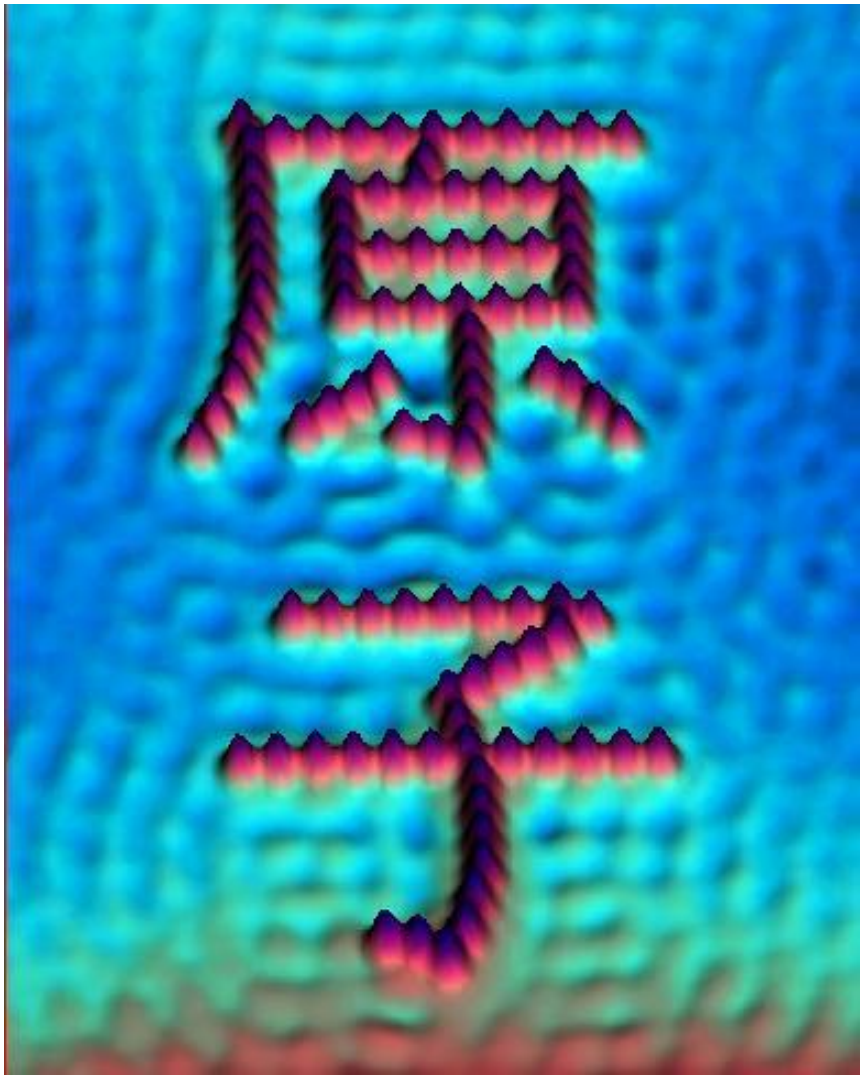
Or, we can say the mass of *one mole* (or the **molar mass**) of ^{12}C atoms is 12 g mol^{-1}.

What is the molar mass of baseball?!



6.02×10^{23} baseballs roughly equals Mass of the earth

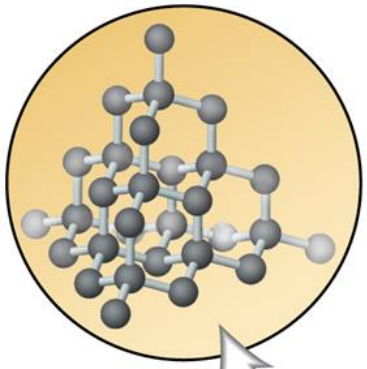
Nowadays We Can Visualize Individual Atom by Advanced Techniques



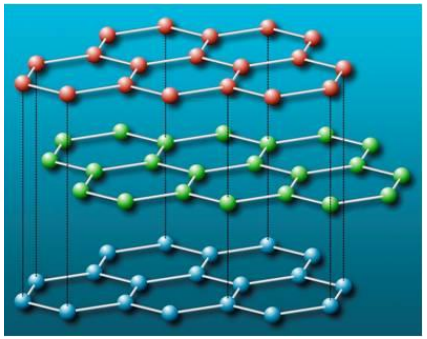
"Iron on Copper"

— Image originally created by IBM Corporation

Chemical Bonds

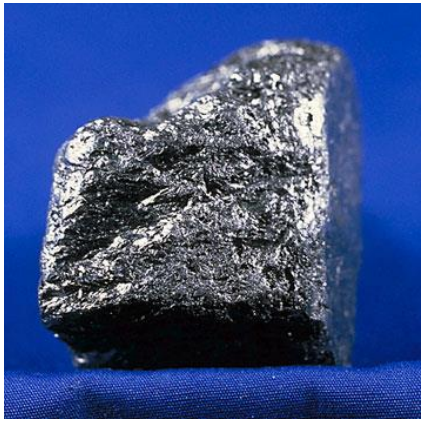


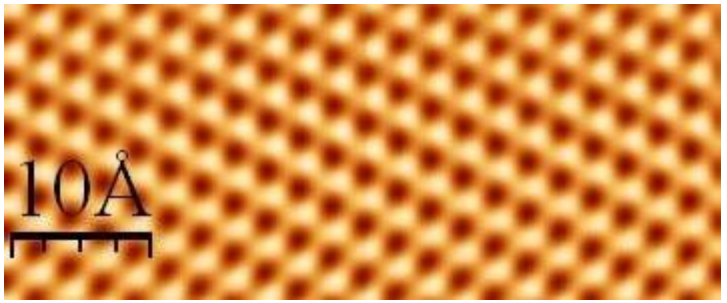
Diamond



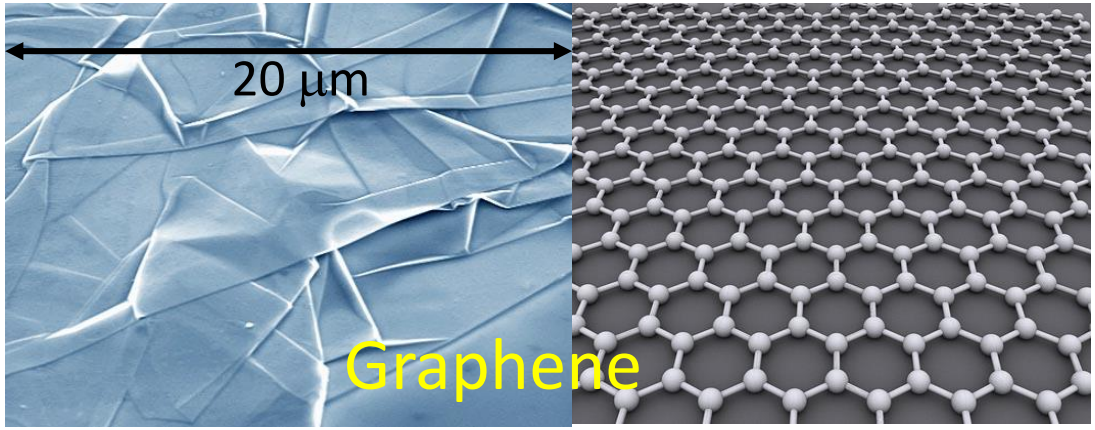
Graphite

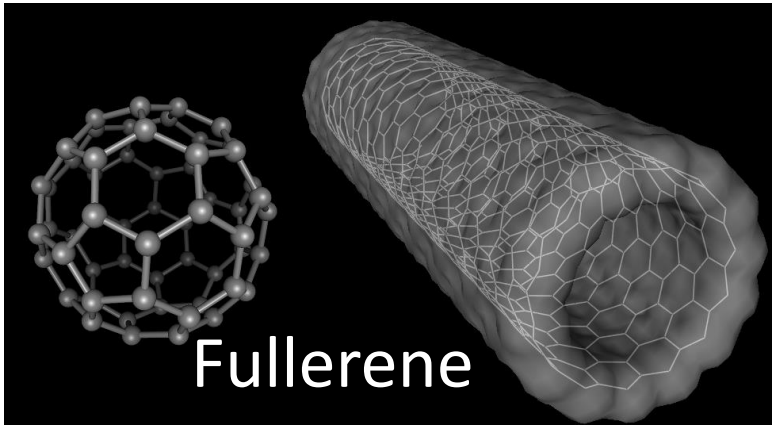
All these materials are only composed of ***carbon atoms****, which are linked together by* ***chemical bonds****; these are* results of ***rearranging electrons*** when reactive atoms encounter each other.





An atomic resolution image of the surface of a graphite

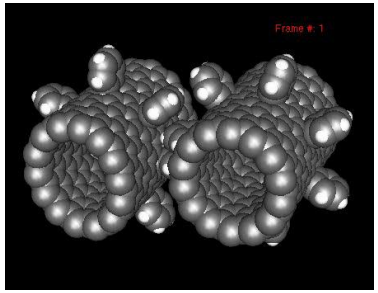


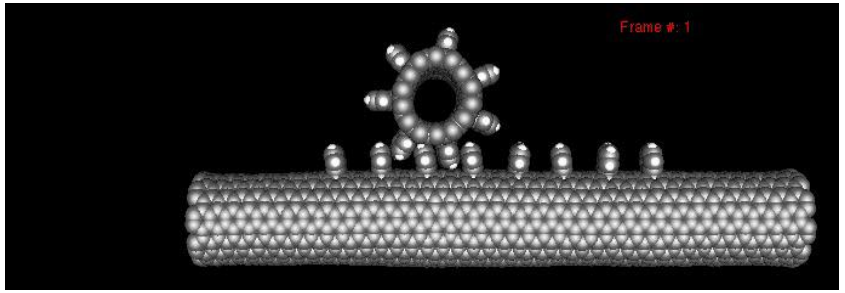


Understanding Chemical Bonding Provides Opportunities to Develop New Materials

Carbon Nanotube Gears

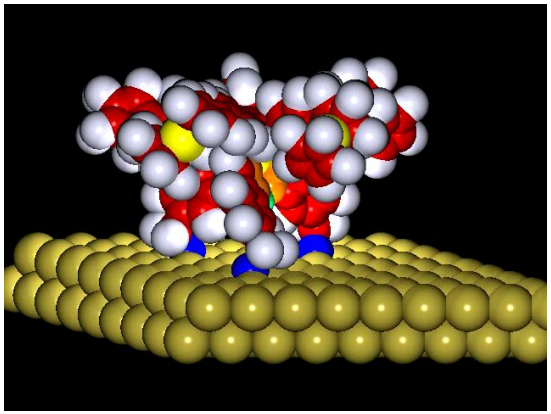
Reference:
J. Han, A. Globus, R. Jaffe, G. Deardorff, "Molecular Dynamics Simulations of Carbon Nanotube-based Gears" *Nanotechnology* **1997**, *8*, 95-102.

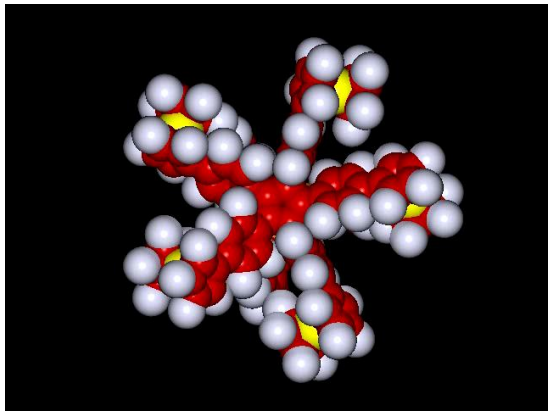




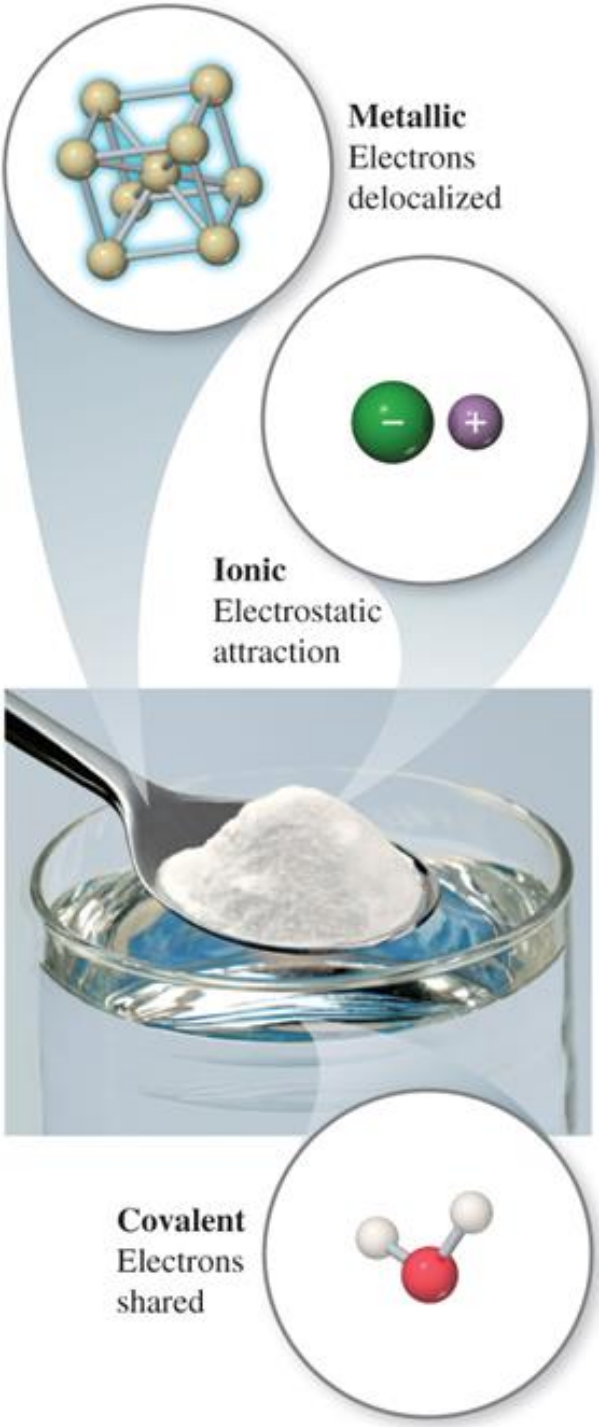
Molecular motors

Reference:
U. G. E. Perera, F. Ample, H. Kersell, Y. Zhang, G. Vives, J. Echeverria, M. Grisolia, G. Rapenne, C. Joachim, S-W. Hla "Controlled clockwise and anticlockwise rotational switching of a molecular motor" *Nature Nanotechnology* **2013***, 8*, 46–51.



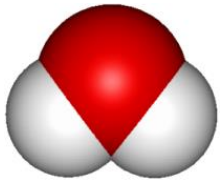


Types of Chemical Bonding



- There are three major types of chemical bonds:
  - **Metallic bond**:
    Delocalization of valence electrons throughout metal atoms in the three-dimensional lattice.
  - **Ionic bond**:
    Electrostatic forces between oppositely charged ***ions.***
    - **cations:** positively charged ions
    - **anions**: negatively charged ions
  - **Covalent bond**:
    Sharing of valence electrons between two atoms.
- Two or more atoms of different elements joined together by chemical bonds form ***chemical compounds***.

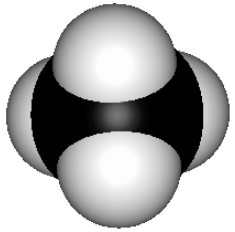
Joining Groups of Atoms Together by Covalent Bonds Will Form Molecules



Water
H_2O

For examples:

- **Water molecule** is a covalent compound formed from one oxygen atom and two hydrogen atoms.
- **Methane molecule** is also a covalent compound formed from one carbon atom and four hydrogen atoms.



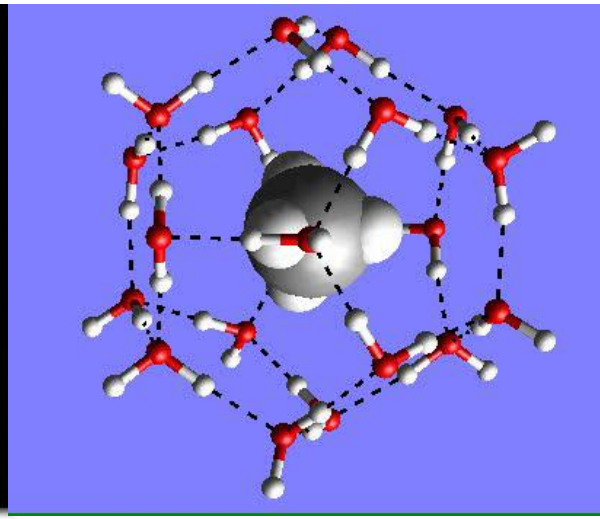
Methane
CH_4

Methane hydrates are cage compounds formed between **water molecules** and **methane molecules** in deep oceans.

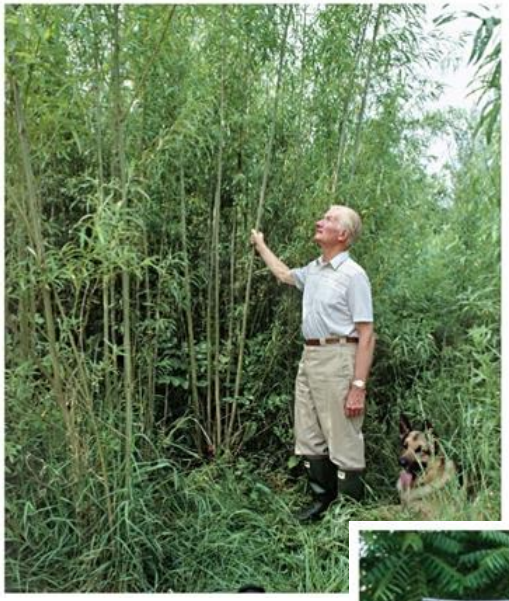
- They are potential extra sources of fossil fuel.
- Combustion of **methane molecules** in air (**oxygen molecules**) produces **water molecules** and **carbon dioxide molecules** and also heat.

$$CH_4 + 2\,O_2 \rightarrow CO_2 + 2\,H_2O + \text{heat}$$

A flaming gas snow ball

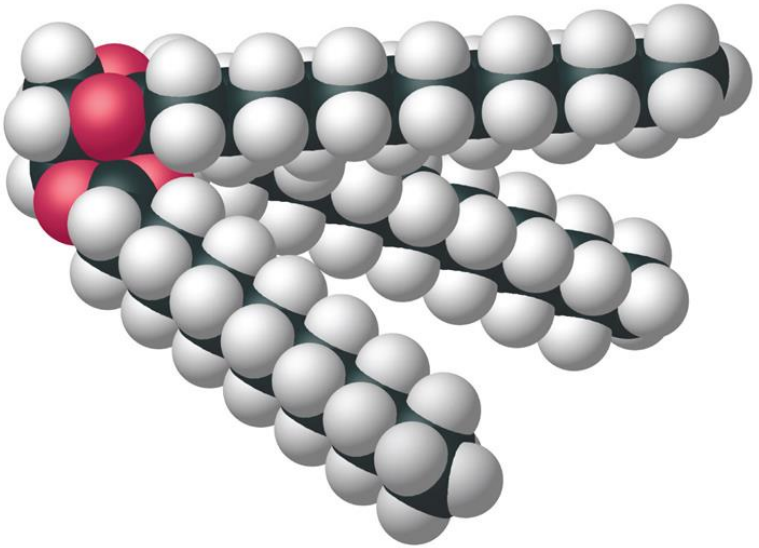


Biomass As a Replacement of Fossil Fuel



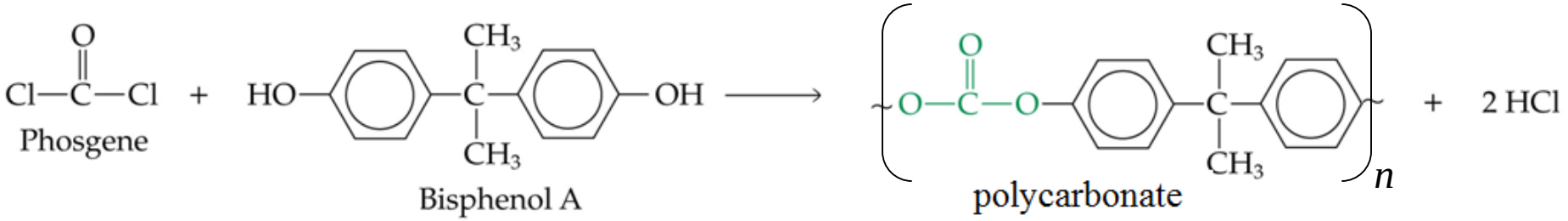
"Photosynthesis for Fuel"

- Combustion of agricultural waste,
- fermentation of **starch and sugar molecules** from plants to **ethanol molecules**, and
- bacterial breakdown of plants to **methane molecules** have all being used as sources of renewable energy.



- Biodiesel can be produced by reacting methanol or ethanol with molecules of vegetable oils or animals fats (**triglyceride molecules**)

Plastics — Giant Molecules



- Polycarbonates (a type of plastics) are lightweight but very strong molecules, made from, for example, phosgene and bisphenol A (BPA).

- Chronic toxicity could be induced by the leached BPA molecules, which act like an estrogenic hormone.

Ions Are Atoms or Groups of Atoms with Charges

Atoms and ions are distinctively different.

- When atoms ***lose*** electrons, they become ***positive*** ions, called as **cations**.
- When atoms ***gain*** electrons, they become ***negative*** ions, called as **anions**.

- We will definitely not take the elemental form of iron (Fe) as iron supplement.
- A common pharmacological form of iron is ferrous sulfate (or iron(II) sulfate), which is an ***ionic compound*** formed between an iron(II) cation (Fe^{2+}) and a sulfate anion (SO_4^{2-}).
- *Can you name some common pharmacological forms of calcium (Ca) supplements?*

Photochromic Lenses contain silver chloride (AgCl) and copper(I) chloride (CuCl) crystals embedded in the glass.

In the presence of sunlight,

- ***Chloride ions*** react with ***silver ions*** to form ***chlorine atoms*** and ***silver atoms***, which can darken the lenses.

$$Cl^- + Ag^+ \rightarrow Cl + Ag$$

In the absence of sunlight,

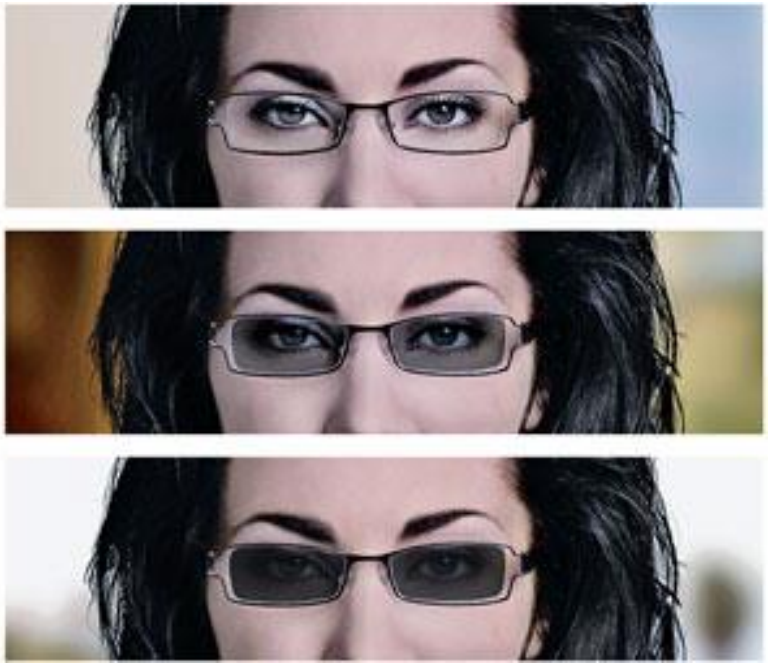
- ***Chlorine atoms*** react with ***copper(I) ions*** to form ***chloride ions*** and ***copper(II) ions***.

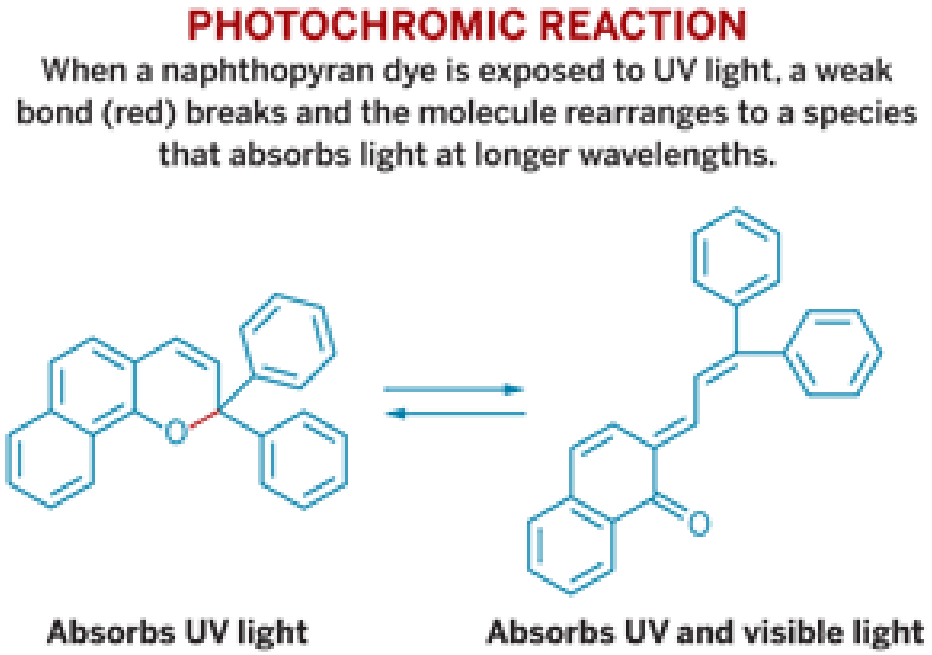
$$Cl + Cu^+ \rightarrow Cl^- + Cu^{2+}$$

- The resulting ***copper(II) ions*** react with ***silver atoms*** to form ***silver ions*** again.

$$Ag + Cu^{2+} \rightarrow Ag^+ + Cu^+$$

Molecular-based Photochromic Lenses

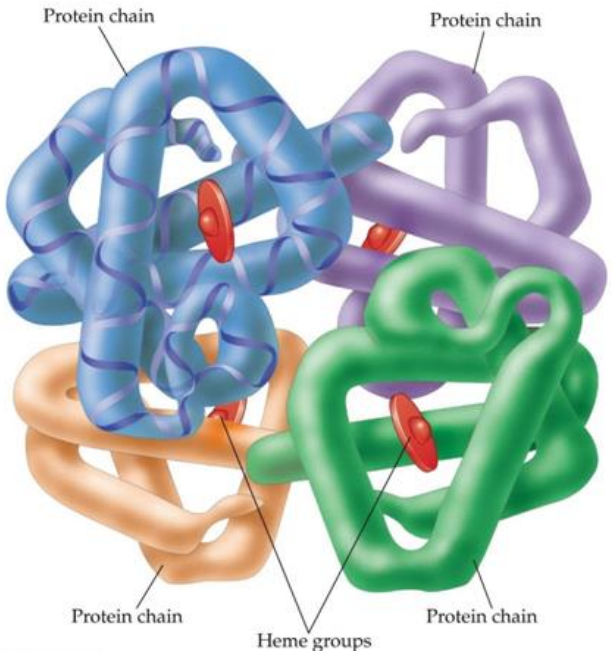


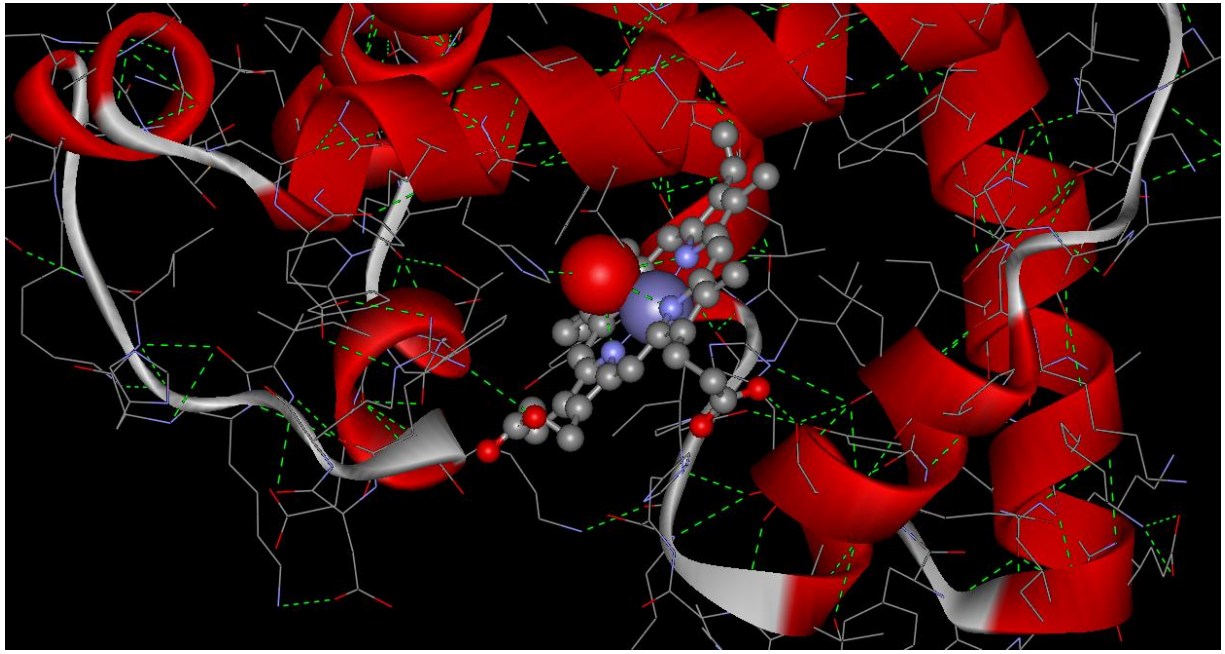


"Self-Darkening Eyeglasses: The science behind dual-purpose lenses"

B. Erickson, *Chemical & Engineering News*, **2009**, *87*, 54.

Hemoglobin: A Big Biomolecule for Transportation of Small Oxygen Molecules (O_2) and Carbon Dioxide Molecules (CO_2) in Blood





- The ionic part of the hemoglobin molecule (i.e. the **iron(II) ion**, Fe^{2+}) in our red blood cells is responsible for carrying the **oxygen molecules** and **carbon dioxide molecules** throughout our body.