Ch2. Atoms, Molecules and Ions

The structure of matter includes:

Atoms: composed of electrons, protons and neutrons.
Molecules: two or more atoms may combine with one another to form an uncharged molecule.
分子內作用力: covalent bond 共價鍵
分子分子間作用力: 一般通稱 van der waals force or hydrogen bond

Ions：spices of opposite charge found in all ionic compounds.

§ 2-1 Atoms and the Atomic theory.

John Dalton：atomic model of matter（in 1808）

1. An element is composed of tiny particles called atoms. ⇨同位素

   ($^{1}_{1}H$, $^{2}_{1}H$, $^{3}_{1}H$)

2. In ordinary chemical reaction, atoms move from one substance to another, but no atom of any element disappears or is changed into an atom of another element. ⇨核反應

   $^{4}_{2}He^{+2} + {}^{9}_{4}\mathrm{Be} \rightarrow {}^{12}_{6}\mathrm{C} + {}^{1}_{0}\mathrm{n}$

3. Compounds are formed when atoms of two or more elements combine, and the relative numbers can be expressed as integers or simple fractions.

   ⇨ 同素異形體 (不定形碳, 石墨, 鑽石)

道耳吞原子說 can explain three basic laws of chemistry：

1. Law of conservation of mass 質量不滅
   There is no detectable change in mass in an ordinary chemical reaction.
2. Law of constant composition 定比定律
   A compound always contains the same elements in the same proportions by mass.
   H_2O: H 佔 11.19%; O 佔 88.81%.

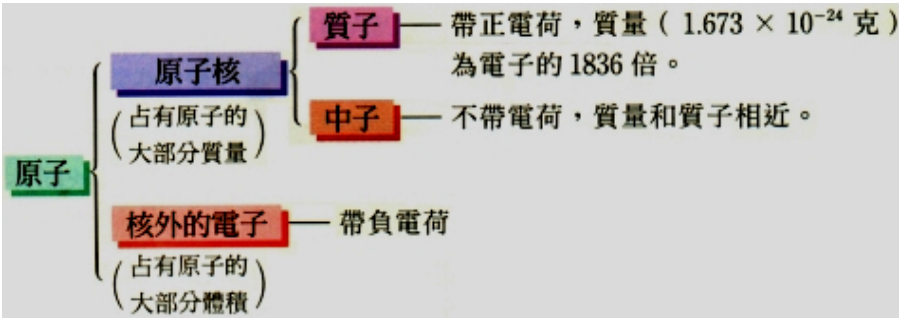
3. Law of multiple proportions 倍比定律

Two elements form more than one compound. The mass of one element with a fixed mass, then the second element are in a ratio of small whole numbers.

H_2O ； H_2O_2 其中 H 之重量固定; 則 O 之重量比 = 1：2

§ 2-2 Components of the atom：

Electrons, protons and neutrons:



§ Electrons：

J.J. Thomson：

When the glass tube is partially evacuated and connected to a spark coil, and electric current flows through it. Associated with this flow are colored rays of light called cathode rays (陰極射線).

1. 在抽真空低壓玻璃管引入不同氣體，並施以高電壓至管內，其所產生之 electron flows called cathode rays.

陰極

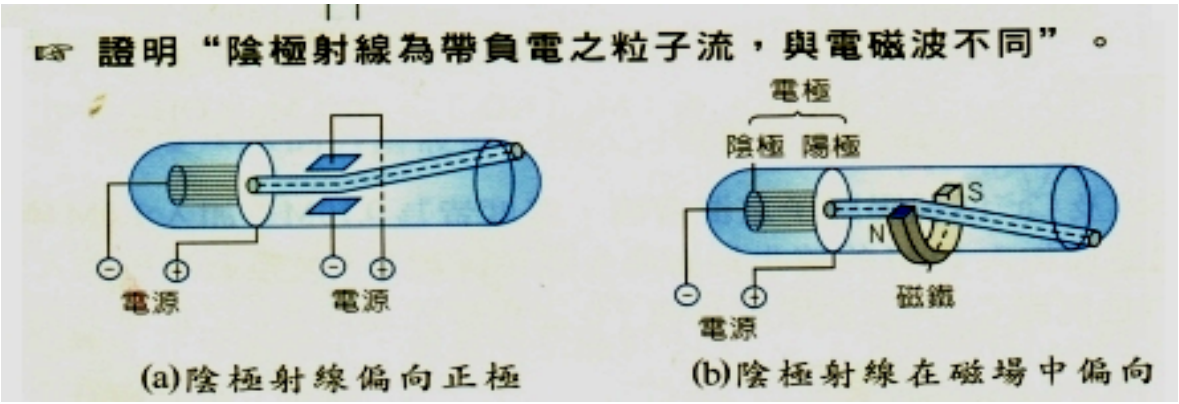
⇩

陰極射線

Stream of negatively charged particles.

⇩

電子

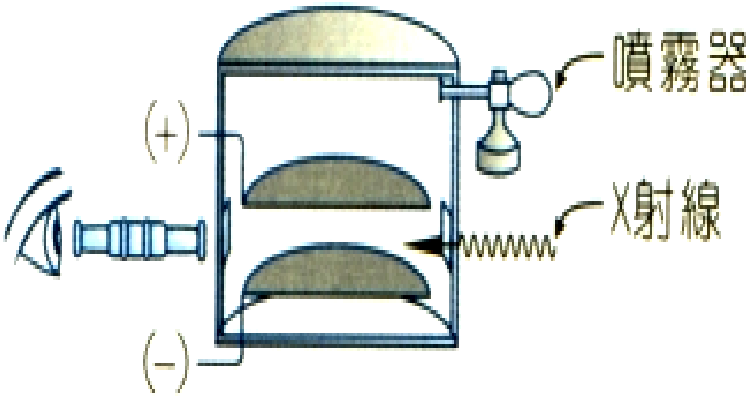


2. $e/m = -1.759\times10^{8}\ coul/g$

Milliken 油滴實驗: 電子之電量 $e = -1.602\times10^{-19}\ coul$

電子之質量 m: $-\dfrac{1.602\times10^{-19}}{m} = -1.759\times10^{8}$

$m = 9.11\times10^{-28}\ g$



原理：利用帶電荷的油滴受電場的影響，和重力下降達平衡的關係可計算出油滴所帶的電荷量 (重力＝電場的作用力⇒ M · G＝ Q · E)

結論:

由 J.J. Thomson 得到 $e/m = -1.759\times10^{8}\ coul/g$

由 Milliken 得到 $e = -1.602\times10^{-19}\ coul$

所以得到電子的質量： $-\dfrac{1.602\times10^{-19}}{m} = -1.759\times10^{8}$

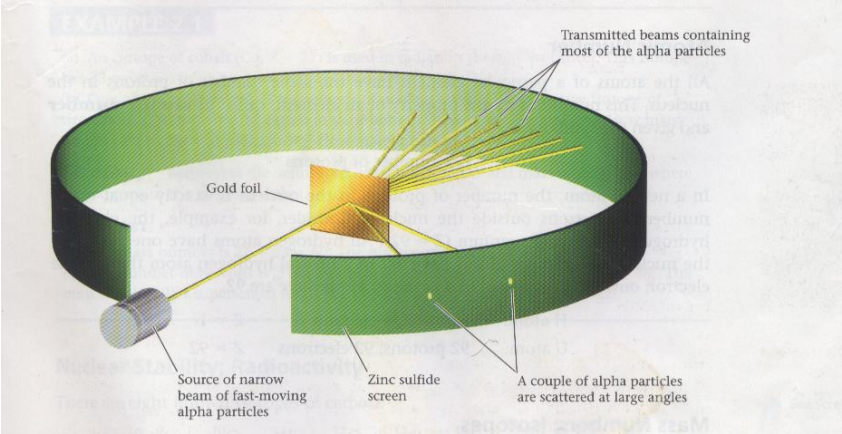
$m = 9.11\times10^{-28}\ g$

§ Protons and Neutrons; the Atomic Nucleus:

Ernest Rutherford: bombarded a piece of thin gold foil with

拉塞福　　α particles ⇨ 金箔實驗

$$^{4}_{2}He^{+2} + {}^{14}_{7}\mathrm{N} \rightarrow {}^{17}_{8}\mathrm{O} + {}^{1}_{1}\mathrm{p}$$



原理：

以 α 粒子撞擊金箔片來研究原子結構.

結果：

1. 大多數的 α 粒子穿過金箔但不偏折.
2. 小部份 α 粒子穿過金箔發生大角度的偏折.
3. 極少部份 α 粒子呈現 180^0 反彈回來.

結論：

1. 正電荷集中原子核而非均勻分布在原子內.
2. 正電荷及質量均集中在極小的原子核中.
3. 原子內有原子核直徑約 $10^{-15}m$；電子之圍繞外圍，直徑約 $10^{-10}m$.
4. 原子核含帶正電之質子，及不帶電之中子.

Chadwick 查兌克：1932, 以 α 粒子撞擊鈹原子, 發現不帶電子粒子⇒中子

$$^{4}_{2}He^{+2} + {}^{9}_{4}\mathrm{Be} \rightarrow {}^{12}_{6}\mathrm{C} + {}^{1}_{0}\mathrm{n}$$

Protons and neutrons are located at the center of an atom called the nucleus (原子核). Electrons are dispersed around the nucleus.

Code	Particle	Location	Charge unit	Charge (coulomb)	Atom mass unite (g)
${}_{1}^{1}p$	Proton	Nucleus	+1	$+1.6022\times10^{-19}$	1.673×10^{-24}
${}_{0}^{1}n$	Neutron	Nucleus	0	0	1.675×10^{-24}
${}_{-1}^{0}e$	Electron	Outside nucleus	-1	-1.6022×10^{-19}	9.109×10^{-28}

§ Atomic Number 原子序 (Z)

In a neutral atom, the number of protons in the nucleus.

For neutral atom：

${}_{1}H$: 1 proton; 1 electron; Z = 1

${}_{92}U$: 92 protons; 92 electrons; Z = 92

§ Mass Number (質量數); Isotopes (同位素)

A = Number of protons + number of neutrons

質量數 A

X 元素符號

原子序 Z

Number of neutrons＝mass number (A)－number of protons

Isotopes：同位素

Atoms that have the same number of protons but different numbers of neutrons are called **isotopes.**

Atomic number (Z) = number of protons

例：^{235}U, ^{238}U

	Z	A	number of protons	Number of neutrons
$^{235}_{92}U$	92	235	92	235 – 92 = 143
$^{238}_{92}U$	92	238	92	238 – 92 = 146

$^{1}_{1}H$, $^{2}_{1}H$, $^{3}_{1}H$

$^{2}_{1}D$, $^{3}_{1}T$
氘 氚

Ex 2-1：(a) An isotope of cobalt (Co，Z＝27) is used in radiation therapy for cancer. This isotope has 33 neutrons in its nucleus. What is its nuclear symbol？

(b) One of the most harmful components of nuclear waste is radioactive isotope of strontium $^{90}_{38}Sr$; it can be deposited in your bones, where it replaces calcium. How many protons are in the nucleus of Sr-90？How many neutrons？

(c) Write the nuclear symbol for the element used in diagnostic bone scans. It has 31 protons and 38 neutrons.

a) Co: Z = 27, has 33 neutrons $\Rightarrow$ $^{33+27}_{27}Co$ $\Rightarrow$ $^{60}_{27}Co$

b) $^{90}_{38}Sr$ (鍶) $\Rightarrow$ The number of protons = 38; The number of neutrons 90 – 38 = 52.

c) $^{31+38}_{31}Ga$ $\Rightarrow$ $^{69}_{31}$Ga

§ Nuclear Stability; Radioactivity 放射能

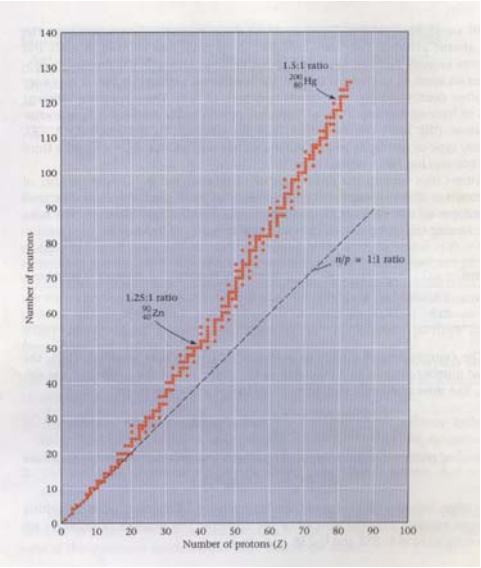


Fig 2.5. Neutron-to proton ratios of stable isotopes.

The neutron –to-proton ratio required for stability varies with atomic number.

1) For light elements: $Z < 20$ 穩定帶 $\frac{A-Z}{Z} \to 1$（this ratio is close to 1）

2) As atomic number increase, Z ↑ $\frac{A-Z}{Z}$ ↑ → 1.5 the belt of stability shifts to higher numbers of neutrons.

3) 比值不落在此穩定帶內者, 具放射性.

C 之同位素:

$\underbrace{{}^{9}_{6}C \quad {}^{10}_{6}C \quad {}^{11}_{6}C}_{\text{unstable}} \quad {}^{12}_{6}C \quad {}^{13}_{6}C \quad \underbrace{{}^{14}_{6}C \quad {}^{15}_{6}C \quad {}^{16}_{6}C}_{\text{unstable}}$

Unstable isotopes decompose (decay) by a process referred to as radioactivity. The result is the transmutation of elements.

放射線種類:

1. β particles: ${}^{0}_{-1}e$
2. α particles: ${}^{4}_{2}H^{+2}$ ⇒ Ch. 19
3. γ ray: high energy radiation.

⇒ ↑ § ⇓ →∴∵ ∼ – “C-1” ↳ ⇒ · ↵