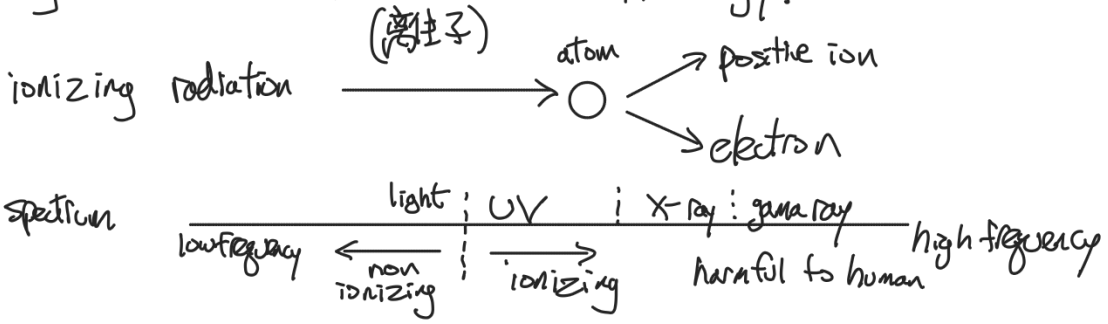
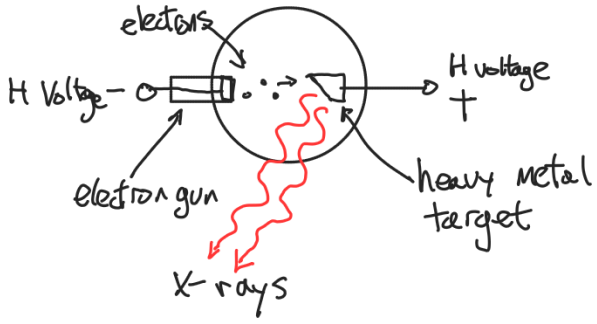
5.1 Ionizing Radiation

Radiation : Transfer of energy from one place to another

Ionizing Radiation : Use ion (離子) to transfer energy.



Example : X-Ray



* High speed electrons, hit heavy metal target.
* Some of these KE, is changed to X-ray.

Applications

1. Medical diagnosis (醫學分析) : X rays can go through flesh (肉) but not bones (骨)
2. Security inspection (安檢查) : Metal is reflected, instead of going through.
3. Industrial inspection : Cracks + defects inspection

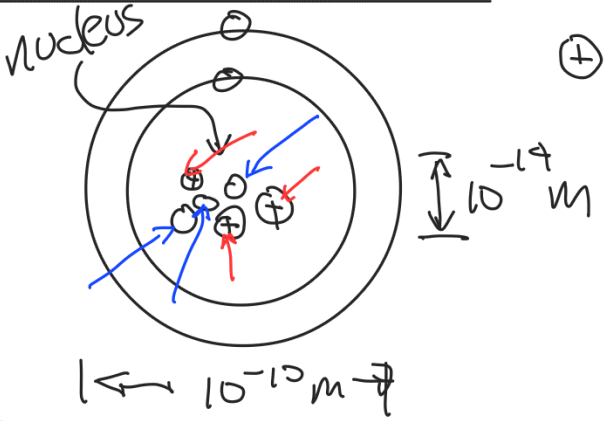
Example : Nuclear Radiation

* Substance that emit ionizing radiation by itself (radioactive)
* Radiation is emitted from the nucleus in atom (nuclear radiation)
* Emission is spontaneous (自發), random (隨機), and unpredictable

* 3 types: α radiation - fast moving helium nuclei (+ve)
β radiation - fast moving electrons (-ve)
γ radiation - very high frequency EM wave

Origin of Nuclear Radiation

Atomic Model



electron -ve
proton +ve Z
neutron 0 ve N
mass number A

Atomic Number : $A = Z + N$ (nuclide notation 核素)

- A: mass number
- Z: number of protons (atomic number)
- N: no. of neutrons

mass number → A
atomic number → Z
element → X

e.g. ${}^{A}_{Z}X$

e.g. ${}^{1}_{1}H$ (hydrogen-1) ; N=0

${}^{4}_{2}He$ (helium-4) N=2

${}^{7}_{3}Li$ (lithium-7) N=4

${}^{12}_{6}C$ (Carbon-12) Carbon-14 neutron 6, 8

Isotopes 同位素 elements that have same Z but different A

e.g. ${}^{1}_{1}H$ N=0, ${}^{2}_{1}H$ N=1, ${}^{3}_{1}H$ N=2 → H_2O 水 軽水 重水

Radio Active Decay 衰變

- Large nucleus are unstable
- Becomes more stable by lowering excessive energy
- By emitting nuclear radiation during radioactive decay. 衰變

α Alpha Decay (escape of $^4_2\alpha$) transmutation

parent nuclide → daughter nuclide + α particle

$$^{208}_{84}Po \longrightarrow {}^{204}_{82}Pb + {}^{4}_{2}He$$

α decay (in general) $$^{A}_{Z}X = {}^{A-4}_{Z-2}Y + {}^{4}_{2}He$$ or $^4_2\alpha$

transmutation 嬗變

Beta Decay (neutron becomes proton + electron)

e.g. $$^{60}_{27}Co \longrightarrow {}^{60}_{28}Ni + {}^{0}_{-1}e$$

cobalt-60 nickel-60

β decay in general $$^{A}_{Z}X \longrightarrow {}^{A}_{Z+1}Y + {}^{0}_{-1}e$$

Gamma Emission

NOT transmutation

even α + β decay, nucleus still unstable, therefore emits γ to become stable

e.g. $$^{60}_{28}Ni^{*} \longrightarrow {}^{60}_{28}Ni + \gamma$$

high energy nickel-60 → low energy nickel-60

$$^{A}_{Z}X^{*} \longrightarrow {}^{A}_{Z}X + \gamma$$

Decay Series (go through different decays)

e.g.

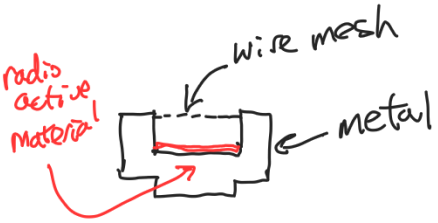
$^{238}_{92}U \xrightarrow{\alpha} {}^{234}_{90}Th \xrightarrow{\beta} {}^{234}_{91}Pa \xrightarrow{\beta} {}^{234}_{92}U \xrightarrow{\alpha} {}^{230}_{90}U$

(uranium 238) — α: ${}^4_2\alpha$; β: ${}^0_{-1}e$; β: ${}^0_{-1}e$; α: ${}^4_2\alpha$

$\cdots\cdots \longrightarrow {}^{206}_{82}Pb$

(lead 206)

Sources of Radiation



* Sealed Sources (for use in lab)

Handle with care!

* Background Radiation (natural sources)
  - Radon Gas
  - Rocks and Soils
  - Cosmic Rays
  - Food, drink, even in our bodies
* Artifical Sources
  - medical and industrial devices
  - consumer products (e.g. cigarette)
  - Nuclear Fallout

Properties of Nuclear Radiation

	α	β	γ	comment
speed	0.05c	0.98c	c	c = speed of light
relative mass	4	≈ 0	0	
relative charge	+2	−1	0	
ionizing power	50k large	500 medium	5 small	no of ion-pairs produced per 1 cm travel
radiation range	0.05m	5m	100m	in air
penetration	low paper	medium aluminum	high lead	material that can stop penetration
electric field deflection	slightly towards −	greatly towards +	No	
magnetic field deflection	↗ slightly	↘ greatly	No	
CLOUD CHAMBER IMAGE