CHAPTER

15

Ionizing Radiations

MAIN TOPICS

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- Ionization
- Ionizing radiation
- Types of ionizing radiations
- Radiation unit
- Hazards of radiation

IONIZATION

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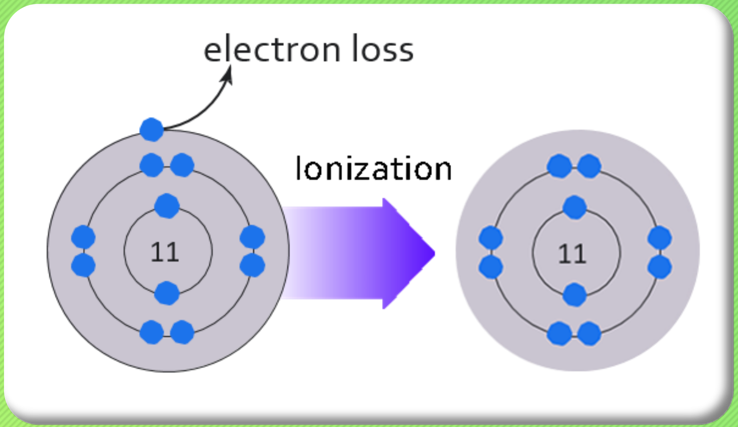
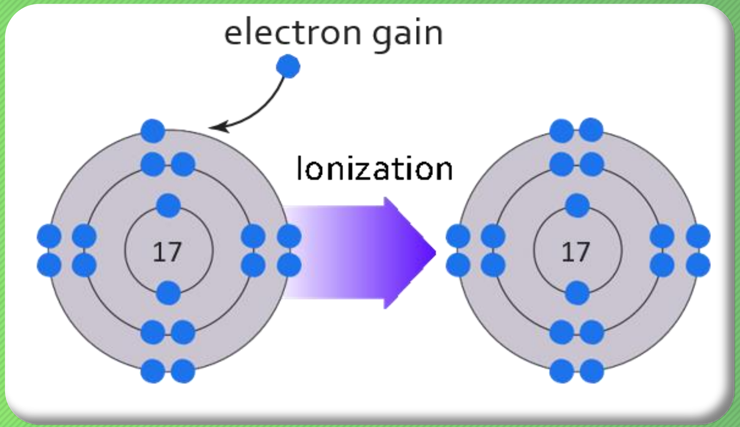
Removal or addition of an electron to the atom is called ionization.





Sodium atom	**Sodium ion**	**Chlorine atom**	**Chlorine ion**
$11p^+$	$11p^+$	$17p^+$	$17p^+$
$11e^-$	$10e^-$	$17e^-$	$18e^-$
charge: 0	charge: +1	charge: 0	charge: –1

IONIZING RADIATION

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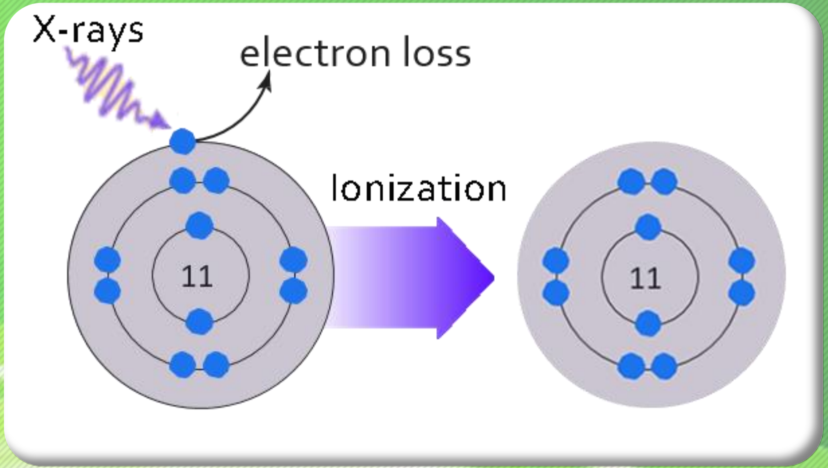
When high energy radiation passes through matter, it leaves a trail of ionized atoms along its path. These radiation which are capable of producing ions are called ionizing radiation.

Ionizing radiation always produce an ion pair.

- The newly freed electron(-)
- The rest of the atom(+).



TYPES OF IONIZING RADIATION

Particulate Ionizing radiation:

These radiations have mass and/or charge

- Alpha rays
- Beta rays (Electrons and Positrons)
- Neutrons

Electromagnetic Ionizing radiation:

These radiations do not have mass or charge

- Gamma rays
- X-rays

ALPHA (α) RAYS

- Alpha rays have mass = 4 a.m.u.
  - 1 a.m.u. ≈ mass of a proton

    1 a.m.u. = 1.67×10^{-27} Kg
- Alpha rays have +2 charge.
- Alpha rays have a typical Energy = 4-8 MeV;
  - Electron volt (eV) = 1.6×10^{-19} Joule
  - Million electron volt (MeV) = 1.6×10^{-13} Joule

ALPHA (α) RAYS

- Alpha rays can travel only for a limited range;
  - 10cm in air
  - 60µm in tissue
- Alpha rays can be shielded by dead skin, film of water, sheet of paper
- Alpha rays are very hazardous when taken into the body

BETA (β) RAYS

- Beta rays have mass = 0.00055 a.m.u.
- Beta rays have –1 charge.
- Beta rays have a typical Energy = few KeV-5 MeV;
  - Kilo electron volt (KeV) = 1.6 x 10^{-16} Joule
- Beta rays can travel for longer range than α-particles;
  - 30cm in air (for 1 MeV β-rays)
  - 4 mm in tissue (for 1 MeV β-rays)
  - 4 cm in wood (for 1 MeV β-rays)

BETA (β) RAYS

- Beta rays can be shielded by 1.5 cm thick aluminum.
- Beta rays are very hazardous internally and can cause skin damage externally.

NEUTRON

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- Neutron have mass = 1 a.m.u.
- Neutron rays have 0 charge.
- Neutron can travel for a long range;
    - 1 m in tissue (for few MeV Neutron)
- Free neutrons are unstable and decay by Beta emission producing an electron (β-rays)and proton This process has half life of approximately 13 min.

GAMMA (γ) RAYS

- Gamma rays have no mass
- Gamma rays have no charge.
- Gamma rays have considerably more energy.
- Gamma rays have speed of light;
  - Speed of light = 3×10^8 m/s
- Gamma rays originate from nucleus of a radioactive atom

GAMMA (β) RAYS

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- Gamma rays can travel for a very long range;
  - Kilometers in air
  - Meters in tissue
- Gamma rays can be shielded only by multimeter thick layer of lead and concrete
- Gamma rays have more penetrating power and these rays can reach to the all organs of the body.

X RAYS

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- When high speed electrons strike a heavy material, they lose energy in the form of X-rays.
- X-rays have no mass
- X-rays have no charge.
- X-rays have more energy than other ionizing radiation but less than that of γ-rays.
- X-rays have speed of light;

X RAYS

- X-rays can travel for a very long range;
  - Meters in air
  - Decimeters in tissue
- X-rays can be shielded by concrete, aluminum or organo-plastics
- X-rays have more penetrating power depends upon the wavelength of the radiations.

RADIATION UNIT

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Four types of radiation measurements are used in various applications:

- Source activity
- Exposure
- Absorbed dose
- Biological quantities

SOURCE ACTIVITY

The source activity A is the decay rate of a radioactive material.

With decay or the rate of decrease in the number of radioactive nuclei present decreases and number of the stable nuclei increases.

unit:

The S.I. unit for source activity is the Becquerel (Bq).

SOURCE ACTIVITY

Becquerel:

Becquerel is one decay per second.

The most commonly used unit for source activity is the Curies (Ci).

Curies:

curie is 3.7×10^{10} decays per second.

1 curie = 3.7×10^{10} Becquerel

EXPOSURE

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Exposure indicates the amount of radiation reaching a material. It is defined as

"The amount of ionization produced in a unit mass of dry air at standard temperature and pressure (STP).

- STP is 1 atmosphere (pressure) and 0˚C(temperature).

- It applies only to gamma and x-rays.
- It depends upon the characteristic of the beam only.

EXPOSURE

unit:

The unit for exposure is the Roentgen (R).

Roentgen:

When radiation produces 2.58×10^{-4} C charge in 1 Kg of air.

$1R = 2.58 \times 10^{-4}$ C/Kg

ABSORBED DOSE

Absorbed Dose indicates the energy absorbed in the material from the radiation beam.

- It applies to all types of radiations.
- It depends upon the characteristic of the beam and the type of the matter or tissue.
- It does not take into account the potential effect of radiation on the body.

ABSORBED DOSE

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unit:

The SI unit for exposure is the Gray (Gy).

Gray:

When 1 kg of matter or tissue absorb 1 joules of energy from radiation.

1Gy = 1 J/Kg

ABSORBED DOSE

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The more commonly used unit for exposure is the Rads.

Rad**:**

1Rad = 0.01 J/Kg

100Rad = 1 Gy

- An exposure of 1R of X-rays or gamma rays produces absorbed dose of 1rad approximately in soft tissue.

BIOLOGICAL QUANTITIES

Absorbed Dose deal with energy absorbed in the material while biological quantities deals with the effects or the damage caused by the radiation on the biological systems.

Quality Factor:

Quality Factor (QF) describes the ability of different ionizing radiation to cause biological damage to the tissue

QUALITY FACTOR

Equal doses of different types of radiation, or different energies of radiation cause different amounts of damage to living tissue.

For example, 1 Gy of alpha radiation causes about 20 times damage as 1 Gy of x- rays.

The equivalent dose was defined to give an approximate measure of the biological effect of radiation.

QUALITY FACTOR

From biological effects of equivalent dose of different radiations, Quality Factor (QF) is calculated

It is calculated by comparing dose of concerned radiation with 200KeV X-rays radiation.

$$\text{Quality Factor (QF)} = \frac{\text{Dose of X-rays (200 KeV)}}{\text{Dose of any radiation}}$$

QUALITY FACTOR

Quality Factor for different type of radiaition

Radiation	QF
X-rays, β-rays, γ-rays	1
Thermal Neutron	3
Fast Neutron, Protons	10
α-rays	20

EQUIVALENT DOSE

unit:

The SI unit for biological equivalent dose is the Sieverts (Sv).

Sieverts:

1Sv = absorbed dose (Gy) x QF

More commonly used unit for biological equivalent dose is the Rem

Rem:

1Rem = absorbed dose (rad) x QF

OCCUPATIONS AT RISK

- Healthcare/Medicine
  - Oncology
  - Radiation therapy
  - Dentistry
- Researchers
- Miners
- Nuclear power plant employees

SYMPTOMS OF EXPOSURE

- High level doses of radiation (more than 100 rads), if received all at once, cause short-term effects, which appear within hours, days, or weeks.
- Initial symptoms:
  - nausea
  - Vomiting
  - malaise

SYMPTOMS OF EXPOSURE

- After latent period:
  - Infections
  - fever
  - hemorrhage
  - loss of hair
  - Diarrhea
  - loss of body fluid
  - CNS effects
- More than 600 rad:
  - death

ADVERSE EFFECTS

- Cancer
- Birth defects
- Cataracts
- Shortening of lifespan
- If reproductive organs irradiated:
  - Genetic mutations may occur in sperm or egg cells