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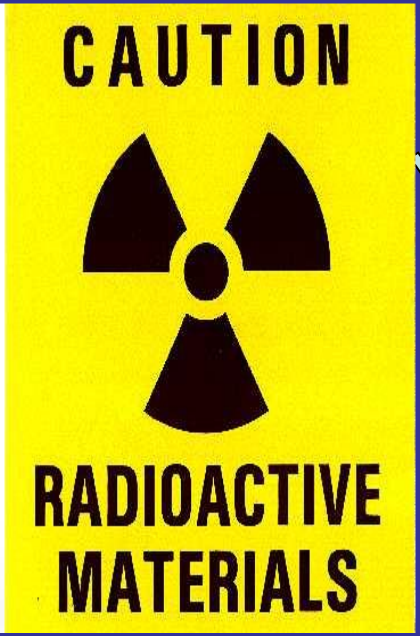
المملكة العربية السعودية
وزارة التعليم العالي
جامعة الإمام محمد بن سعود الإسلامية
كلية العلوم

Solid State Nuclear track Detectors (SSNTDs)

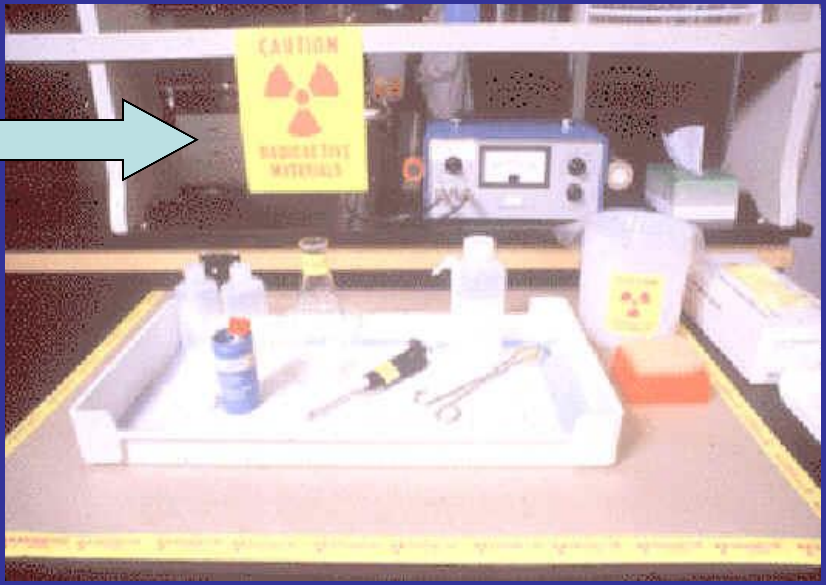
Dr / Basma Elbadry

Outline

- What’s the radiation
- Types of radiation
- Sources of radiation
- Radiation effect on body
- Radiation protection
- Solid State Nuclear track Detectors

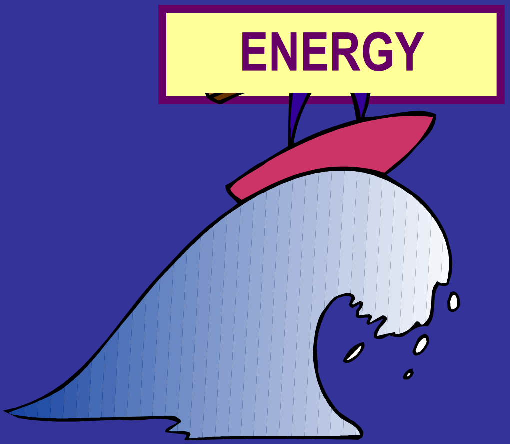

CAUTION
RADIOACTIVE
MATERIALS


CAUTION
RADIATION AREA


CAUTION

What is "Radiation"?

Travels in Waves

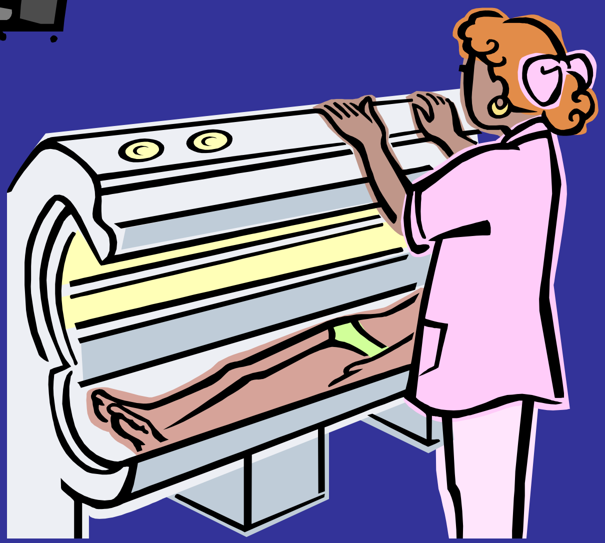


High Speed Particles

Types of Radiation

Non-Ionizing Radiation

Non-ionizing radiation has less energy than ionizing radiation; it does not possess enough energy to produce ions, but can excite the electron. Examples of non-ionizing radiation are visible light, infrared, radio waves, microwaves, and ultraviolet.



Ionizing Radiation

ionizing radiation has higher energy than non-ionizing radiation; it possess enough energy to produce ions.

This process results in the formation of two charged particles or ions:

- molecule with a net positive charge
- free electron with a negative charge

Examples of ionizing radiation are alpha, Beta, neutron, gamma, and X-ray.

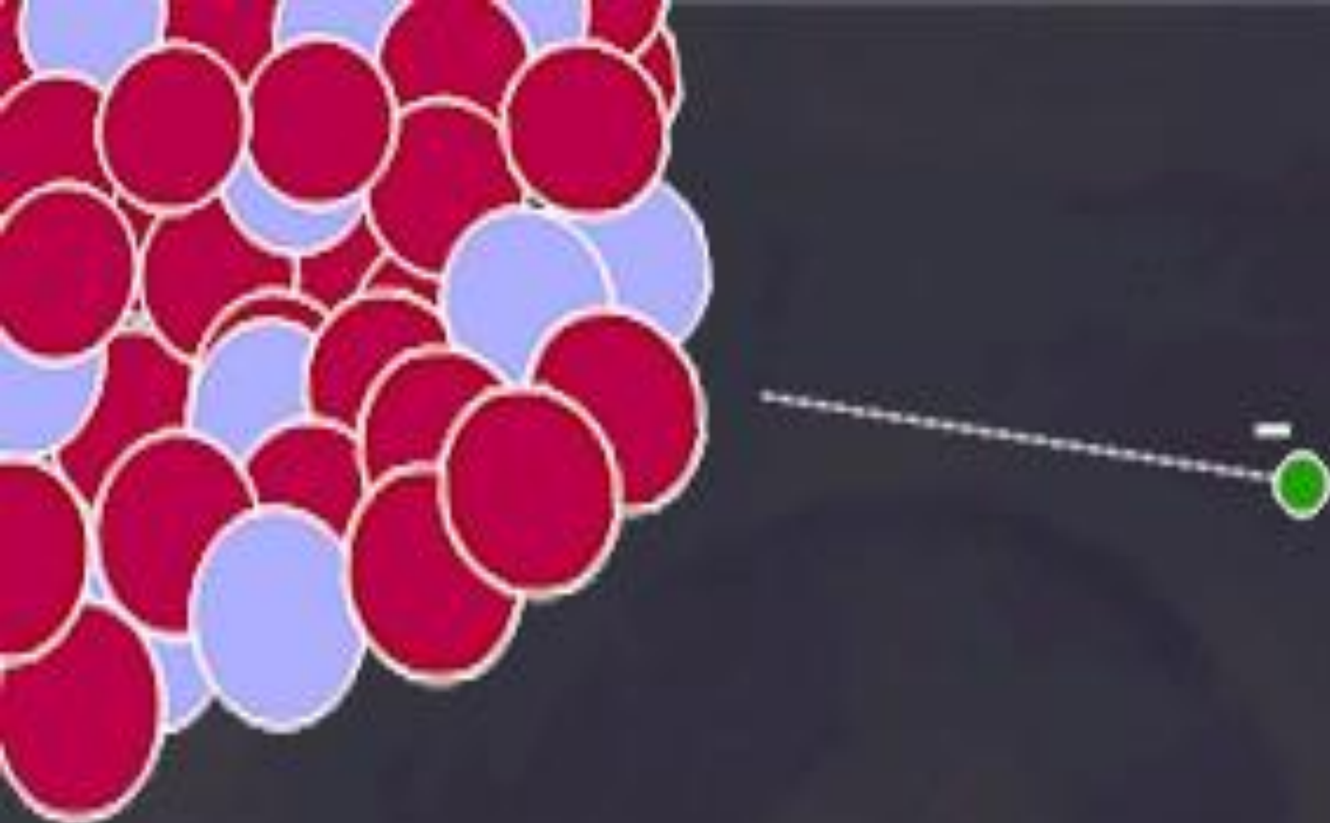
ALPHA PARTICLE

Alpha Radiation (α)

- Helium nucleus (2 neutrons and 2 protons)
- heavy particles, Relatively slow
- **Total charge of +2**
- They travel short distances,
- Only a hazard when inhaled

Mass number changes by 4 and atomic number changes by 2

$${}^{A}_{Z}\mathrm{X} \rightarrow {}^{A-4}_{Z-2}\mathrm{Y} + {}^{4}_{2}\alpha \quad (\text{Note: } {}^{4}_{2}\alpha = {}^{4}_{2}\mathrm{He})$$



BETA PARTICLE

Beta Radiation (β)

- High speed electron or positron ejected from nucleus
- light particles
- Relatively fast moving
- **Total charge of -1 or +1**

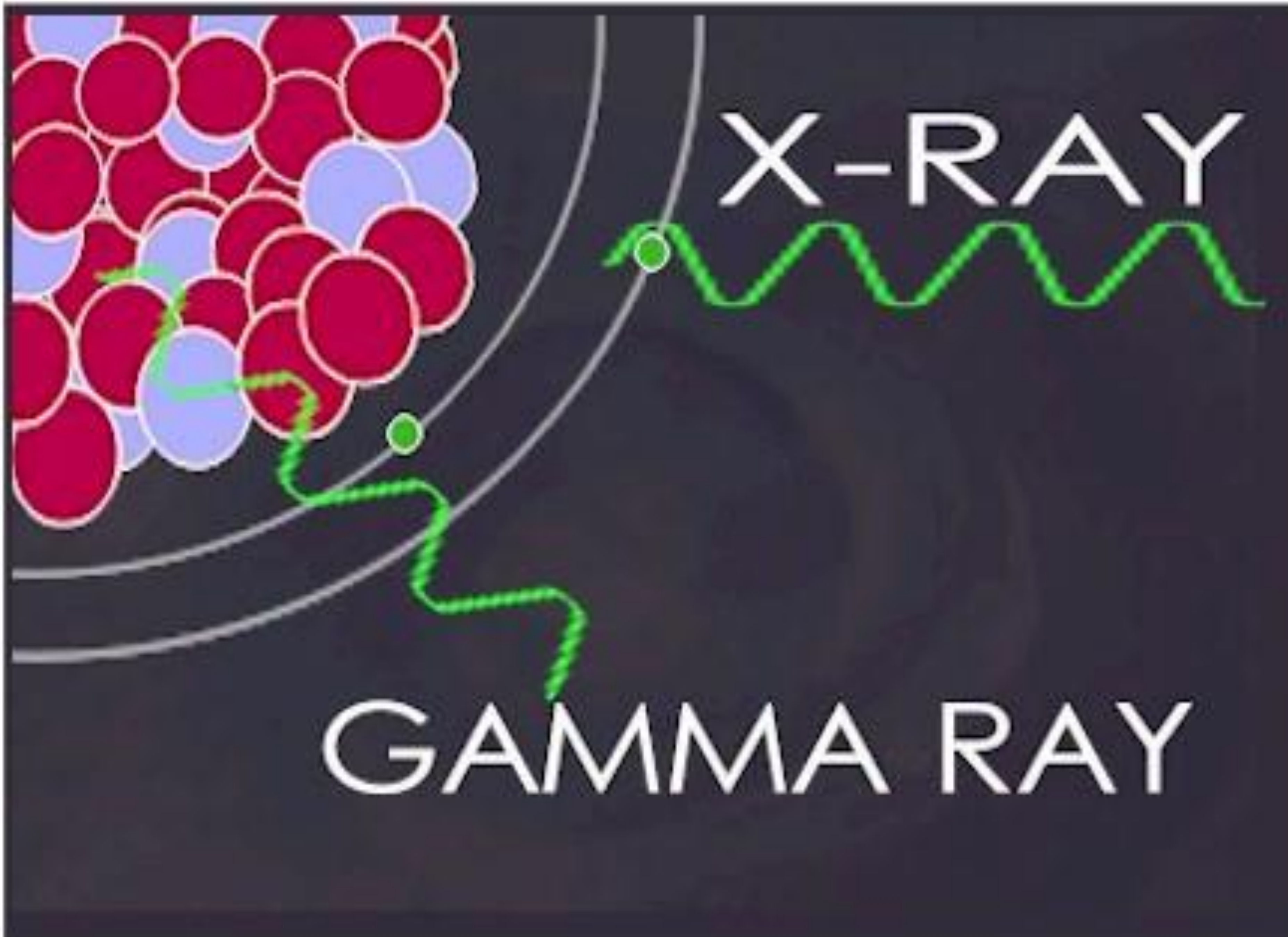
Atomic Mass Number remains constant

$$ {}^{A}_{Z}\mathrm{X} \rightarrow {}^{A}_{Z+1}\mathrm{Y} + {}^{0}_{-1}\mathrm{e} + \bar{\nu} $$

$$ {}^{A}_{Z}\mathrm{X} \rightarrow {}^{A}_{Z-1}\mathrm{Y} + {}^{0}_{+1}\mathrm{e} + \nu $$

$$ {}^{1}_{0}n \rightarrow {}^{1}_{1}p + {}^{0}_{-1}\mathrm{e} + \bar{\nu} $$

$$ {}^{1}_{1}p \rightarrow {}^{1}_{0}n + {}^{0}_{+1}\mathrm{e} + \nu $$

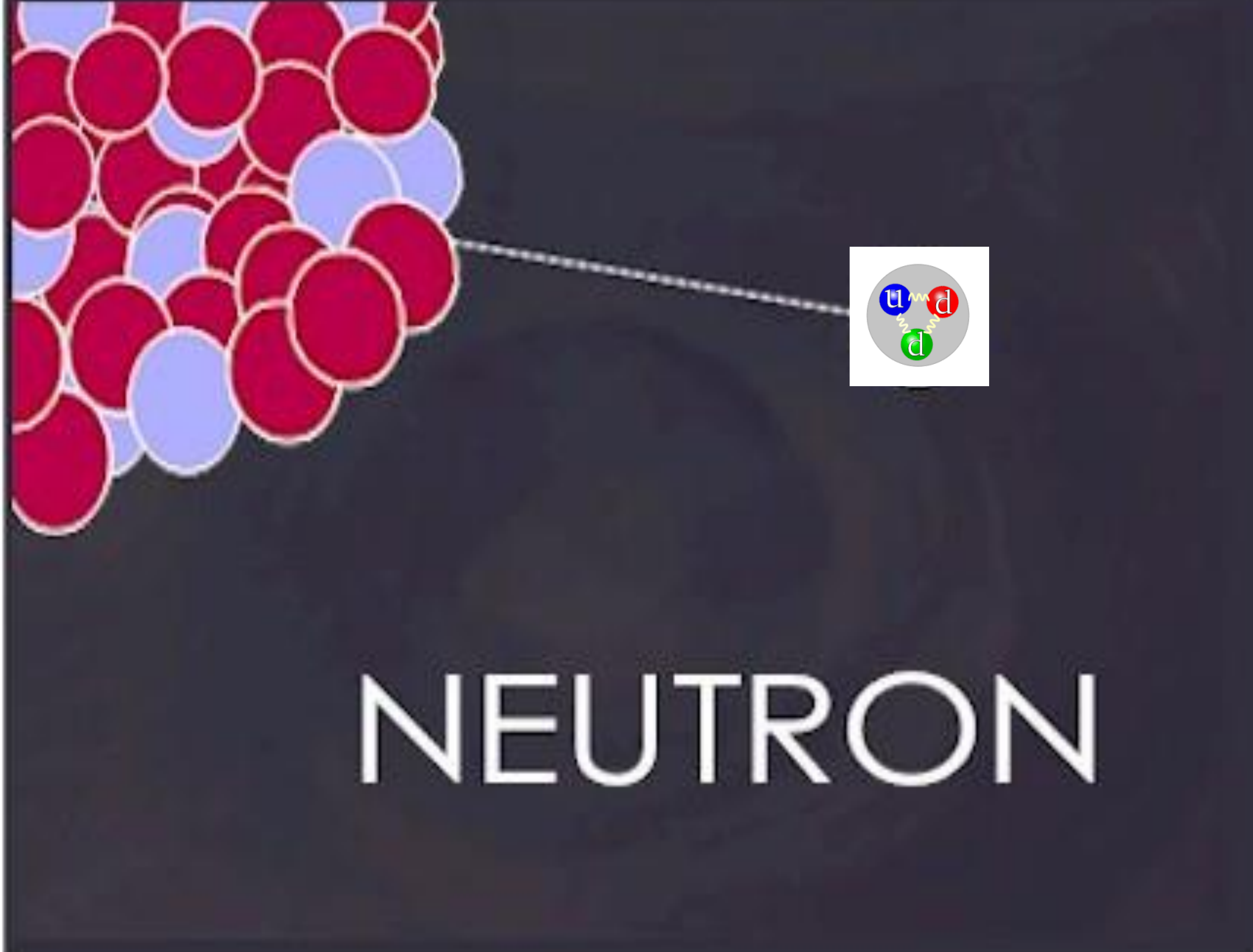

X-RAY
GAMMA RAY

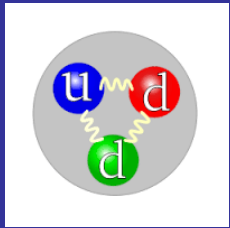
X-Rays and Gamma Rays

- Gamma rays are photons emitted from the nucleus, often as part of radioactive decay.

- X-rays are photons (electromagnetic radiations) emitted from electron orbits, such as when an excited orbital electron "falls" back to a lower energy orbit.

- Gamma rays typically have higher energy (Mev's) than X-rays (KeV's), but both are unlimited.
- No mass; Charge=0; Speed = C.


u
d
d
NEUTRON

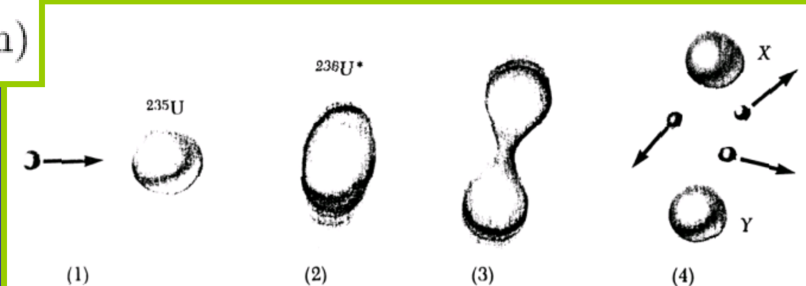


Neutrons

Apart from cosmic radiation, spontaneous fission is the only natural source of neutrons (n). A common source of neutrons is the nuclear reactor, in which the splitting of a uranium or plutonium nucleus is accompanied by the emission of neutrons. The production of nuclear power is based upon this principle. All other sources of neutrons depend on reactions where a nucleus is bombarded with a certain type of radiation (such as photon radiation or alpha radiation), and where the resulting effect on the nucleus is the emission of a neutron. Neutrons are able to penetrate tissues and organs of the human body when the radiation source is outside the body. Neutrons can also be hazardous if neutron-emitting nuclear substances are deposited inside the body. Neutron radiation is best shielded or absorbed by materials that contain hydrogen atoms, such as paraffin wax and plastics. This is because neutrons and hydrogen atoms have similar atomic weights and readily undergo collisions between each other.

- 1 AMU; Neutral Charge;

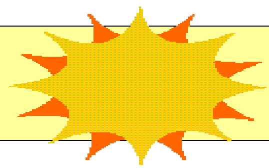
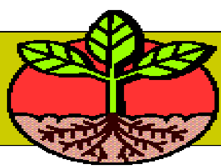
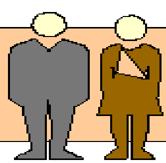
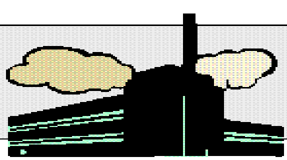
$${}^{1}_{0}\mathrm{n} + {}^{235}_{92}\mathrm{U} \Rightarrow {}^{147}_{57}\mathrm{La} + {}^{87}_{35}\mathrm{Br} + 2\,{}^{1}_{0}\mathrm{n} \text{ (neutron induced fission)}$$



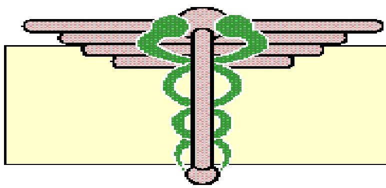
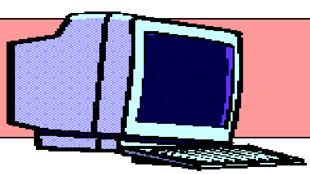
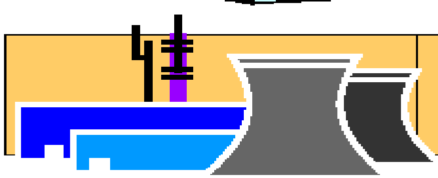
The stages in a nuclear fission event as described by the liquid-drop model


Sources of Radiation

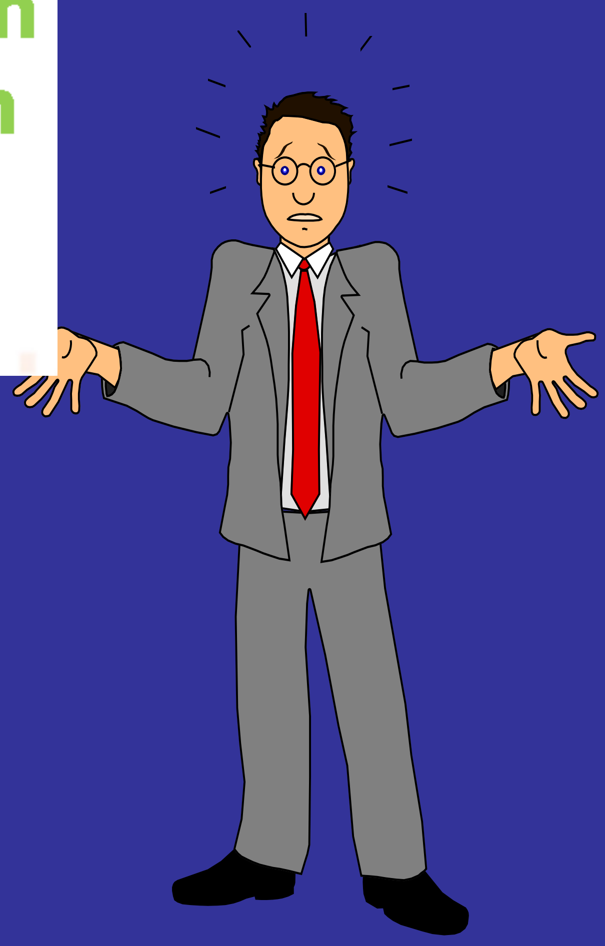
Radiation from Natural Sources

	Source	mrem/year
	Cosmic rays	28
	The earth	26
	Radon	200
	The human body	25
	Building materials	4

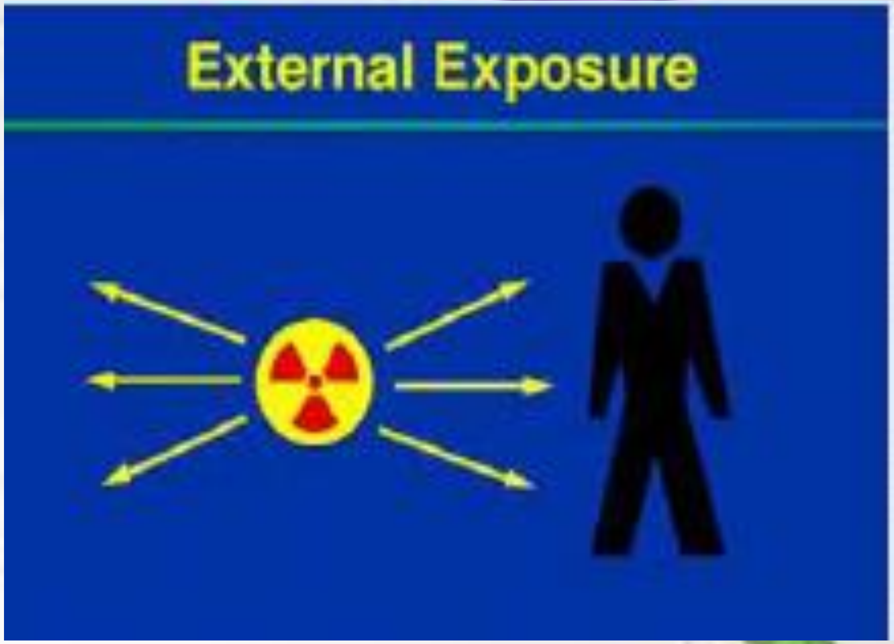
Radiation from Manmade Sources

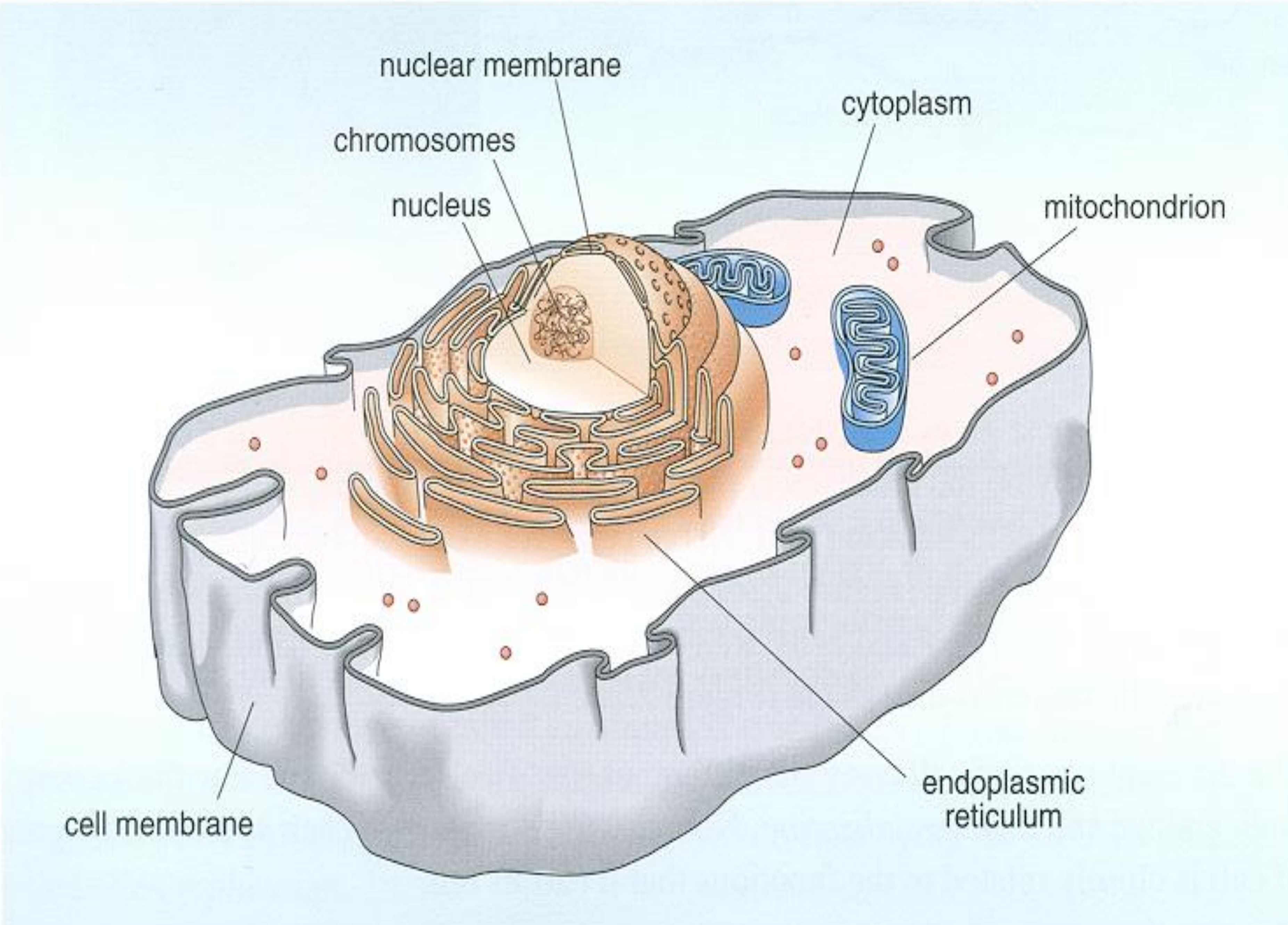
	Source	mrem/year
	Medical	90
	Fallout	5
	Consumer products	1
	Nuclear power	0.3

What could happen to the body when exposed to **radiation?**



Radiation exposure



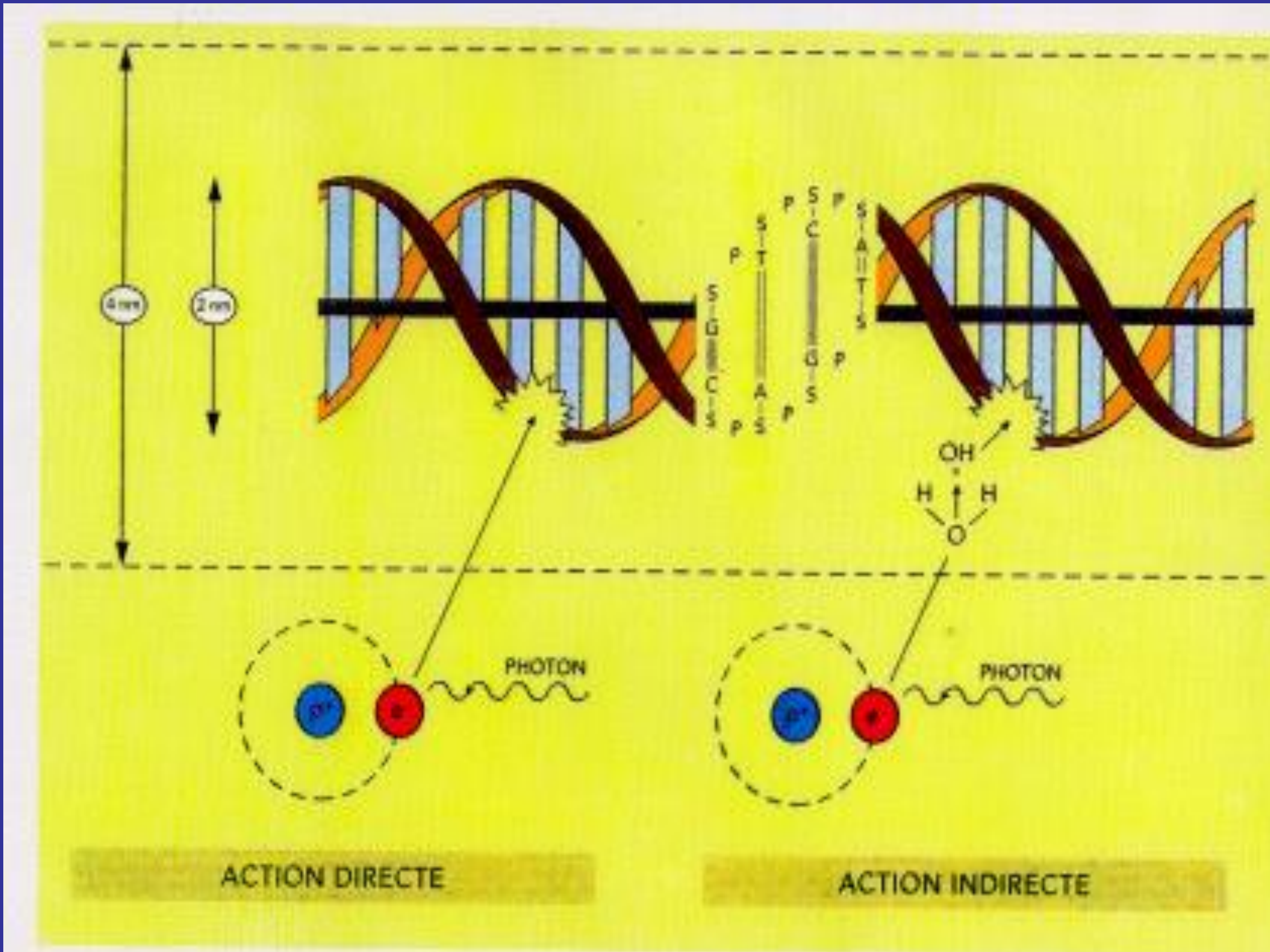

nuclear membrane
cytoplasm
chromosomes
nucleus
mitochondrion
endoplasmic reticulum
cell membrane

Biological effects of radiation

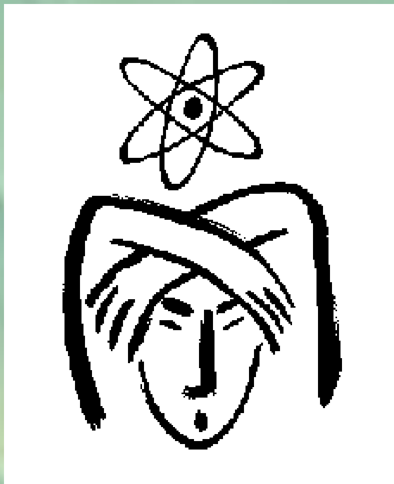
Biological effects of radiation result from both direct and indirect action of radiation.

☞ Direct damage is based on direct interaction between radiation particles and complex body cell molecules, (for example direct break-up of DNA molecules)

☞ Indirect damage is more complex and depends heavily on the energy loss effects of radiation in the body tissue and the subsequent chemistry.


4 nm
2 nm
OH
H
H
O
PHOTON
PHOTON
ACTION DIRECTE
ACTION INDIRECTE

Indirect damage



- **The physical stage (~10^{-16} s)**

$$\text{Photon or particle} + H_2O \longrightarrow H_2O^+ + e^-$$

- **The physico-chemical stage (~10^{-6} s)**

$$H_2O^+ + H_2O \rightarrow H_3O^+ + OH$$

$$H_2O^- \longrightarrow H + OH^-$$

$$e^- + H_2O \longrightarrow H_2O^-$$

$$H_2O^+ \longrightarrow OH + H^+$$

$$\boxed{OH + OH \longrightarrow H_2O_2}$$

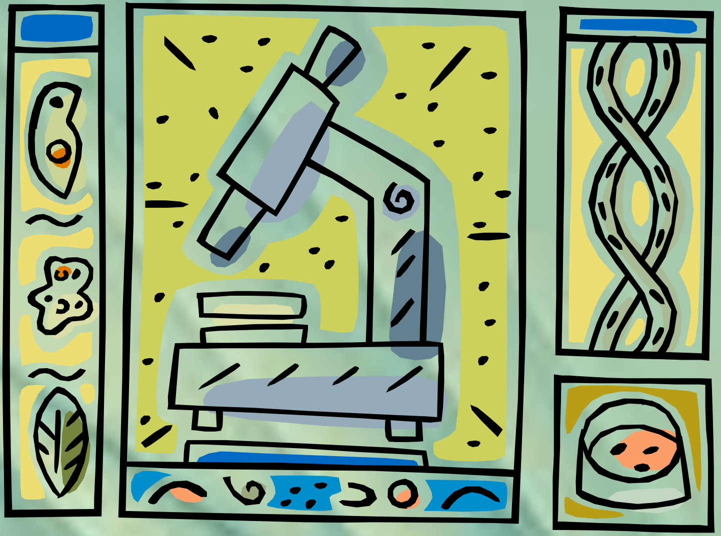
- **The chemical stage (~s)**

OH ,H, H2O2 radical attacks DNA-molecule.

- **The biological stage (min----years)**

Resulting biological damage which can contribute to the destruction of the cell..

Cell Sensitivity



Somatic cells

Gonadal cells

Most sensitive cells:

Rapidly dividing cells
(Small intestines, bone marrow, hair, fetus)

Least sensitive cells:
Slowly dividing cells
(brain, nerves)

Biological Effects of Radiation

- Biological Effects of Radiation can be broken into two groups
- The First Group of biological effects are Stochastic Effects
- The Second Group of biological effects are Deterministic Effects

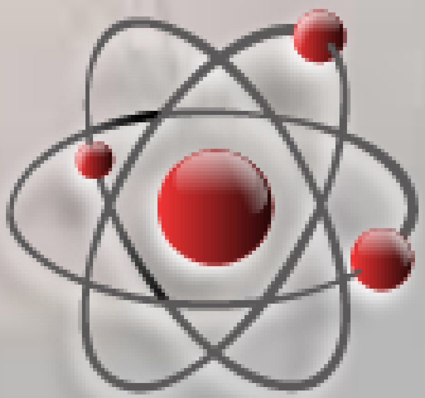
Deterministic Effects

- Deterministic Effects are those responses which increase in severity with increased dose
- For example; sunburn. The more you're exposed to the sun, and the higher the 'dose' of sunlight you receive, the more severe the sunburn

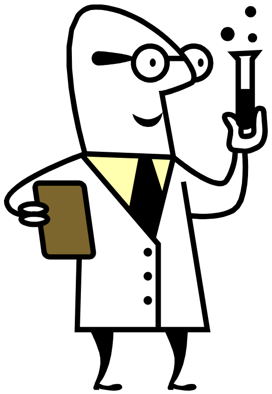
Stochastic Effects

- Stochastic Effects are those effects which have an increased probability of occurrence with increased dose, but whose severity is unchanged
- Example; skin cancer and sunlight. The probability of getting skin cancer increases with increasing exposure to the sun
- Stochastic Effects are like a light switch; they are either present or not present

Radiation Protection



Distance



Inverse Square Law

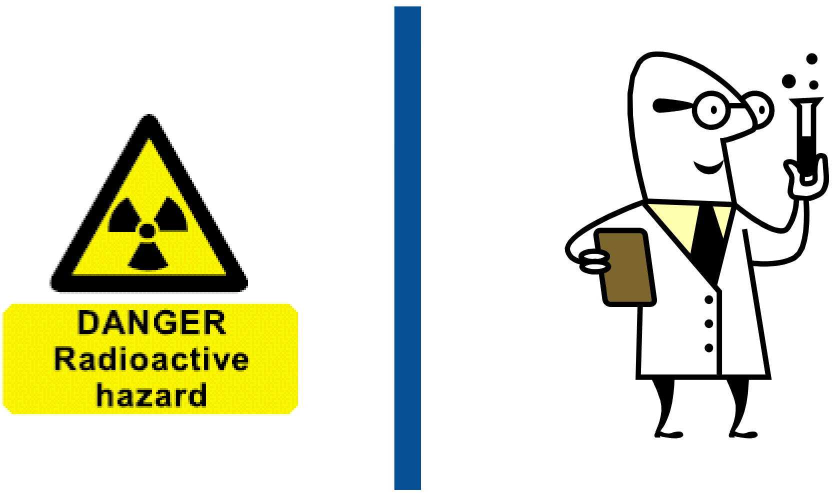
The radiation intensity, I, is proportional to one over the distance squared:

$$I \propto \frac{1}{D^2}$$

The source is assumed to be small compared to the distance.

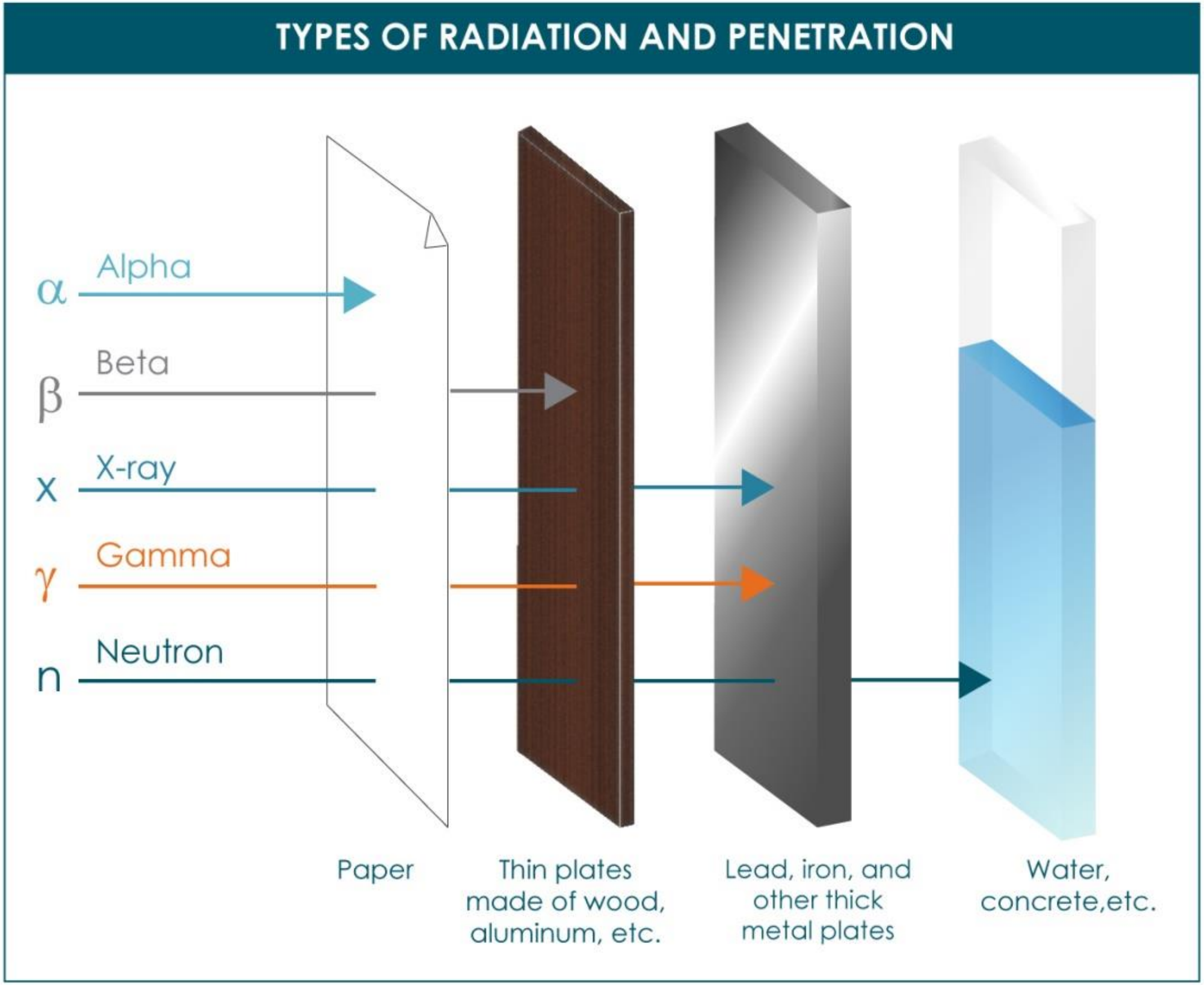
Shielding

Material placed between yourself and the source will reduce your exposure to radiation.



The amount of reduction will depend upon the material and the radiation.

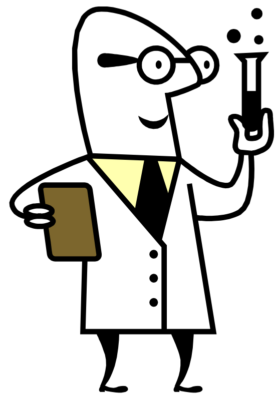
- Material density and thickness
- Radiation type: α, β, γ, or x-ray
- Radiation energy


TYPES OF RADIATION AND PENETRATION
α
Alpha
β
Beta
x
X-ray
γ
Gamma
n
Neutron
Paper
Thin plates made of wood, aluminum, etc.
Lead, iron, and other thick metal plates
Water, concrete,etc.

Time

Minimize the time spent in a radiation field

Containment



Purpose is to ensure that all work and non-work surfaces do not pose a risk to health

Radiation detection

Radiation Detectors

Measurement of ionizing radiation is based on interactions of radiation with matter.

Category of Detectors

Active detectors

- *Ionization chamber*
- *Geiger-Müller counters*
- *Proportional counter*
- *Scintillation detectors*

Passive detectors.

- *photographic emulsions*
- Thermoluminescence *TLD,*
- Solid State Nuclear Track Detectors

Solid-state nuclear track detectors

- A **solid-state nuclear track detector** or **SSNTD** (also known as an **etched track detector)** is a **dielectric materials with specific resistivity (**10^{6}-10^{20}ohm.cm)
- There are two types of these detectors

Organic detectors (Polymers) :

CR_39
CN_85
Makrofol
Lexan
LR-115

Inorganic detectors (Crystals and Glasses):

Muscovite mica
Phosphate glass
Quartiz
Tektile glass
Soda lime glass

The basic principles of SSNTD technique

When a heavily ionizing charged particles passes through such insulating solids, it leaves a narrow trail of damage about 50 Å in diameter along its path. This is called latent track **that may be observed either directly by transmission electron microscope [TEM] provided that the detector is thick enough, viz. some μm across or under ordinary optical microscope after suitable enlargement by etching the medium.**

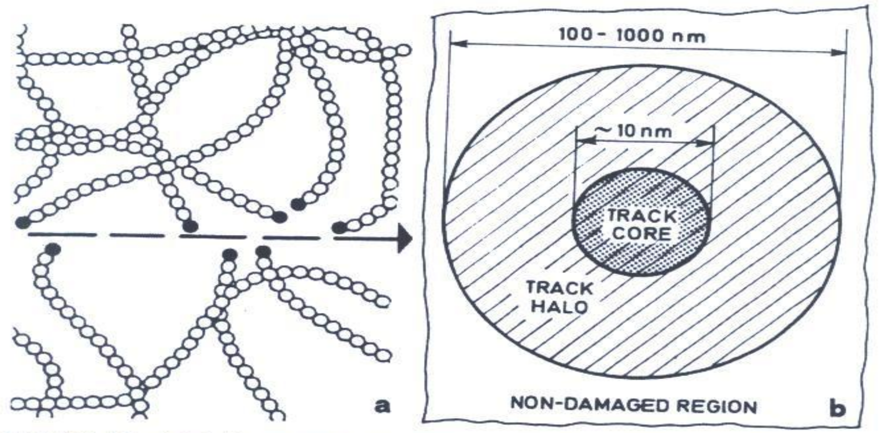


FIGURE 3.1 Axial (a) and radial (b) sections through a particle track in a polymer (not drawn to scale). Chain breaks allow preferential etching at a lower damage density (Ilić, 1990).

Track formation in SSNTDs mainly depends upon

1. Total energy loss rate (-dE/dX)
2. Angle of incidence of the ion with respect to the detector surface.

Track revelation by chemical etching

- The rate of chemical attack along trails of radiation damage is called track etch rate V_T, and that along undamaged bulk material is called bulk etch rate V_B. The shape of the tracks depend upon the ratio of the track etch rate to the bulk etch rate. The activation energy for the damage region is higher as compared to that of remaining bulk material. Therefore $V_T/V_B > 1$ and thus the etchant produces a conical etch pit having a cone angle
- For etched tracks to appear, there is a certain critical angle θc , the angle between the plane of material and the direction of particles below which tracks will not be registered by chemical etching although the condition VT> VB is satisfied .

➢ The size and shape of these tracks yield information about the mass, charge, energy and direction of motion of the particles.

➢ If the particles enter the surface at normal incidence, the pits are circular; otherwise the ellipticity and orientation of the elliptical pit mouth indicate the direction of incidence.

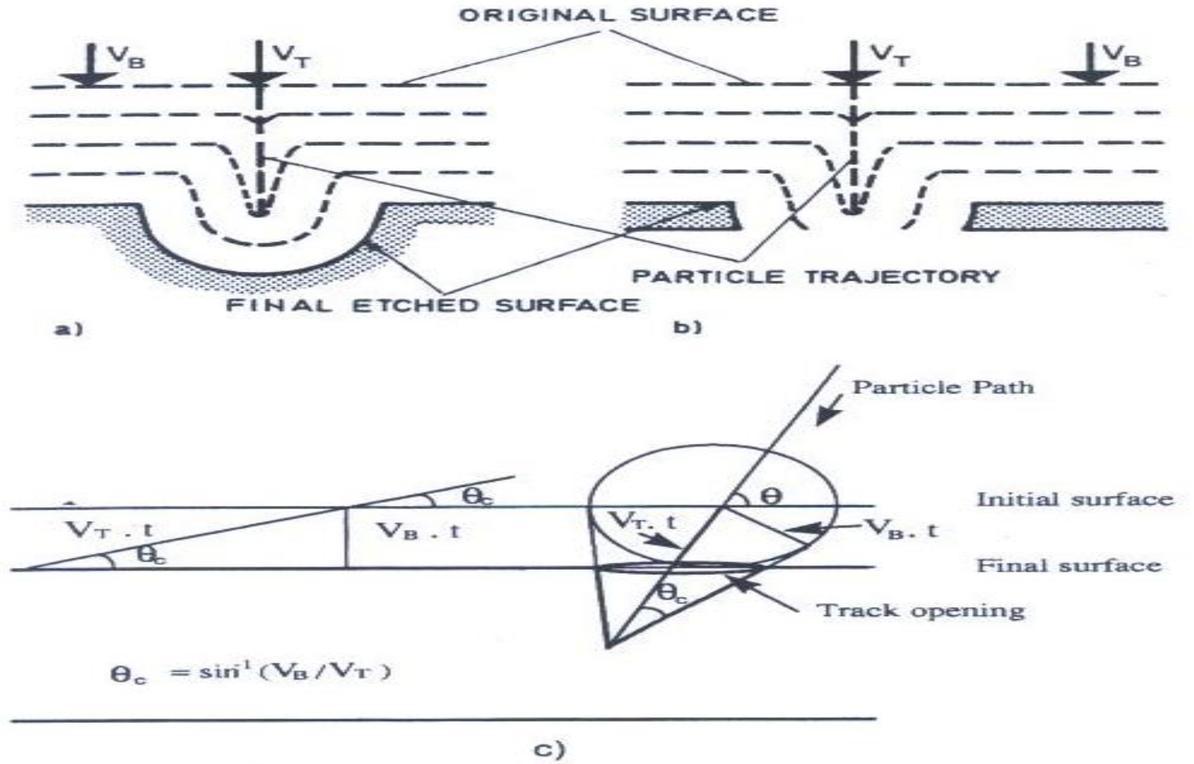


FIGURE 3.3 Schematic representation of track etching in thick (a), and thin (b), detector foils. Development of track profile during the etching process for a particle entering detector surface at 90° is illustrated. Bulk etch rate and track etch rate are denoted by V_B and V_T respectively (Ilić, 1990). (c) Concept of the critical angle of etching. When an irradiated detector is treated with an appropriate etchant, the velocity of etching along the latent track (V_T) is larger than the bulk velocity of etching (V_B) elsewhere in the medium. In the figure shown, the ratio $V_T/V_B = 3$. There is an angle Θ_c for each medium and a given heavy ion such that, by the time that the etchant travels a distance $V_B t$ vertically into the body of the detector, it reaches the end of the range of the particle proceeding along that "dip angle" Θ_c at the same instant – i.e. $V_B t / V_T t = \sin\Theta_c$. Only tracks making dip angles with the detector surface, such that $\Theta > \Theta_c$, will thus leave observable track openings. The half-cone angle of all such etch pits is also $\Theta_c = \sin^{-1}(V_B/V_T)$ (Durrani, 1997).

Chemical Etching

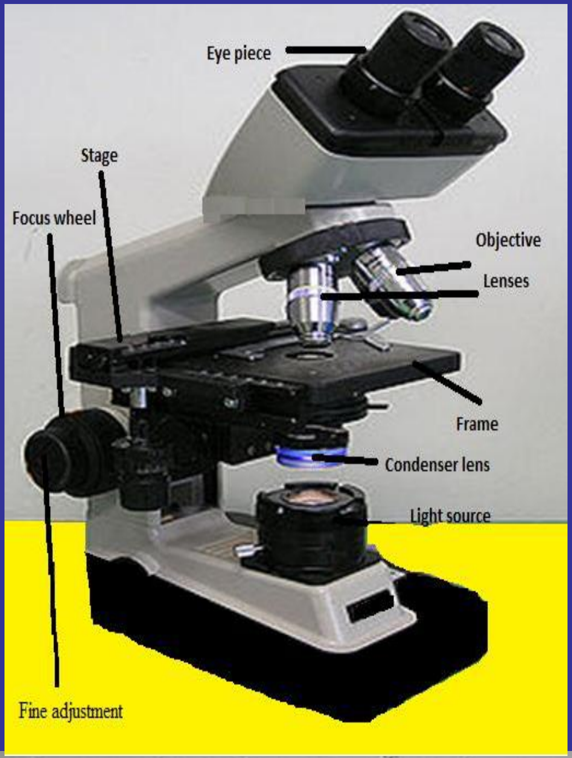
Chemical Etching depends on

- chemical solution type
- concentration of chemical solution
- temperature of chemical solution
- time of etching

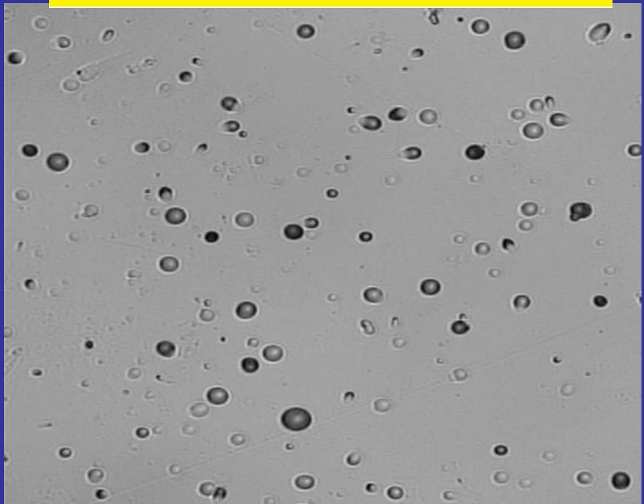
Track Evaluation Methods

Manual (Ocular) Counting:

- After the chemical etching of a detector, the tracks of particle can be easily scanned by an optical microscope using ordinary magnification. The tracks can be easily distinguished from the background scratches etc. in the detector. Optical microscopy has been found to be highly useful and convenient for obtaining track parameters and densities, although the counting through a microscope is a cumbersome process.



- Track densities are expressed either in relative terms or in absolute terms [tracks cm^{-2}] which is converted after calibrating into a dose.
- There are also spark counting and automatic track evaluation.



The reasons for the widespread use of SSNTD

- They are inexpensive, convenient to use and quite robust.
- They can be obtained in any size, from very small to very large (small detectors can be used to measure particle fluxes in odd locations while large detectors are used to record *very* rare events *in* cosmic ray studies).
- The registered tracks are a permanent record of the phenomenon under investigation. In particular, they remain unaffected by changes in atmospheric conditions such as temperature, pressure, humidity etc.
- They are insensitive to visible light. Their development or etching is simple and rapid and does not require dark room facilities.
- They can be used as threshold detectors, e.g. glasses and certain plastics record fission fragment tracks but do not record alpha particle tracks.
- The charge and energy discrimination of these detectors has been found to be better than that of nuclear emulsions.
- They do not need any electronic/electric

Measurements and Applications

- *Earthquake prediction*
- *Geological uses (Uranium exploration)*
- *Radon dosimeter*
- *Neutron dosimeter*
- *Medical and Biological studies*
- *environmental Sciences*
- *Nanotechnology*

Thank you for your attention

Any Questions?