Universitatea POLITEHNICA Bucureşti, Facultatea de Ştiințe Aplicate

Basic concepts in radiological protection and dosimetry

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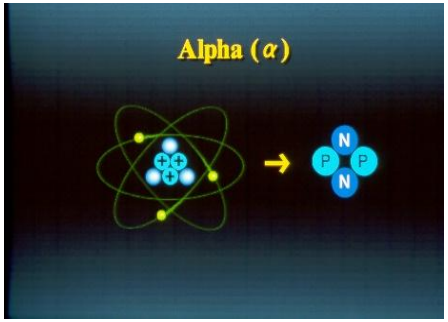
Contents

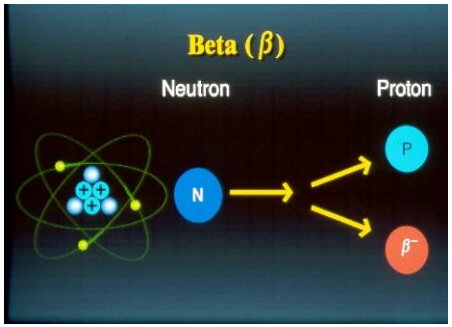
Objective

- To study the radiation protection quantities and associated terminology
- To learn about equivalent dose, radiation weighting factors, effective dose, tissue weighting factors and various operational quantities

Ionizing Radiation

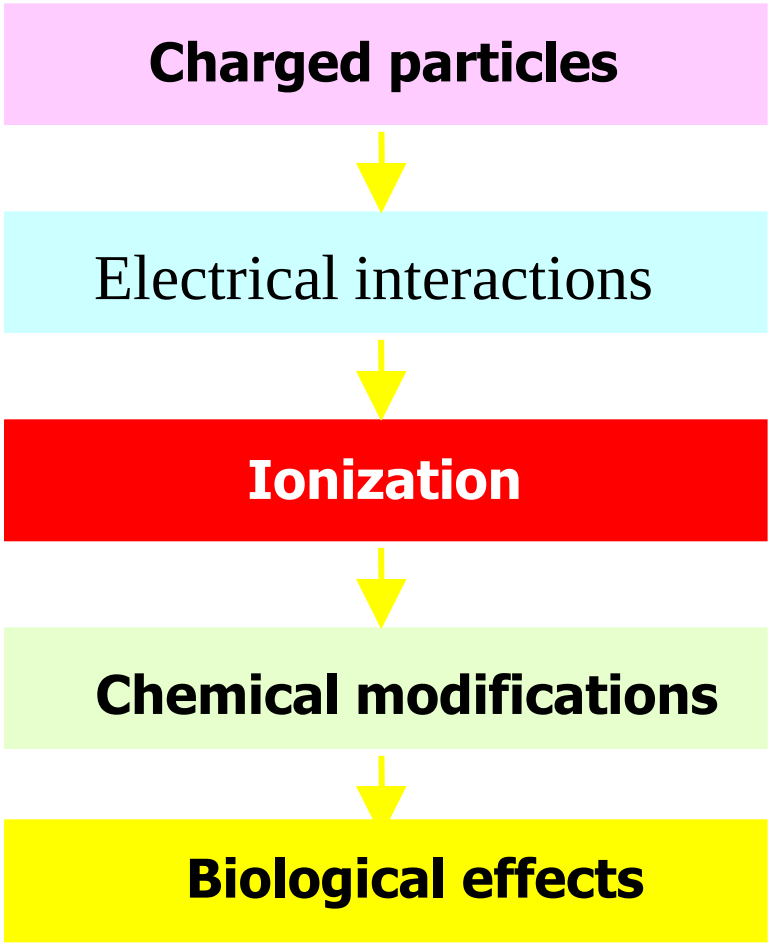
- Directly ionizing radiations
  - α;
  - β.





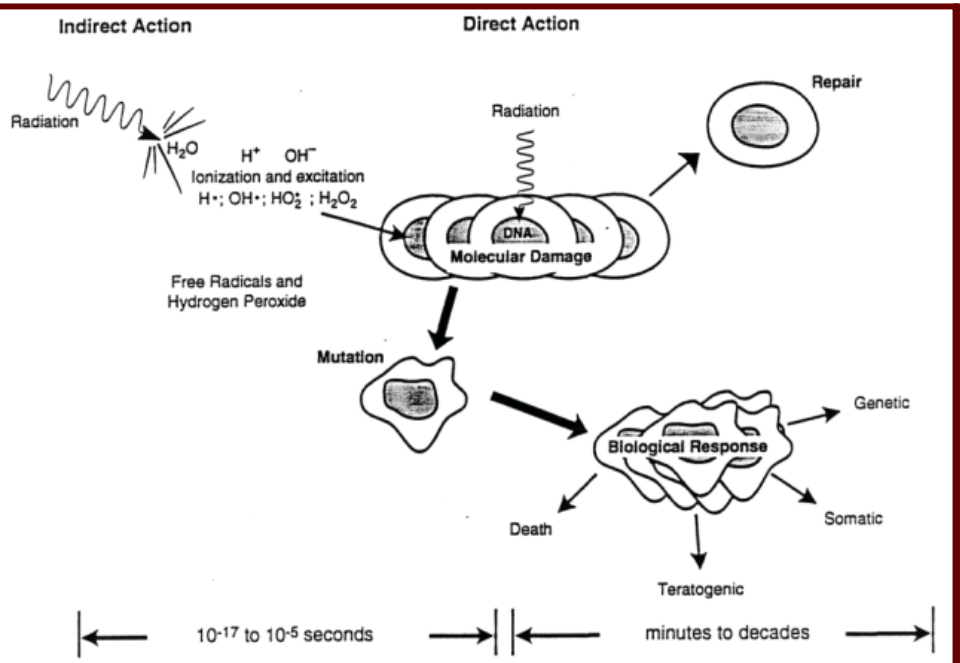
- Indirectly ionizing radiations
  - γ;
  - X;
  - neutron radiations.

Ionizing Radiation



Biological effects of ionizing radiations

The time scales for the short and long term effects of radiation are symbolized in the figure and listed in the table [1]



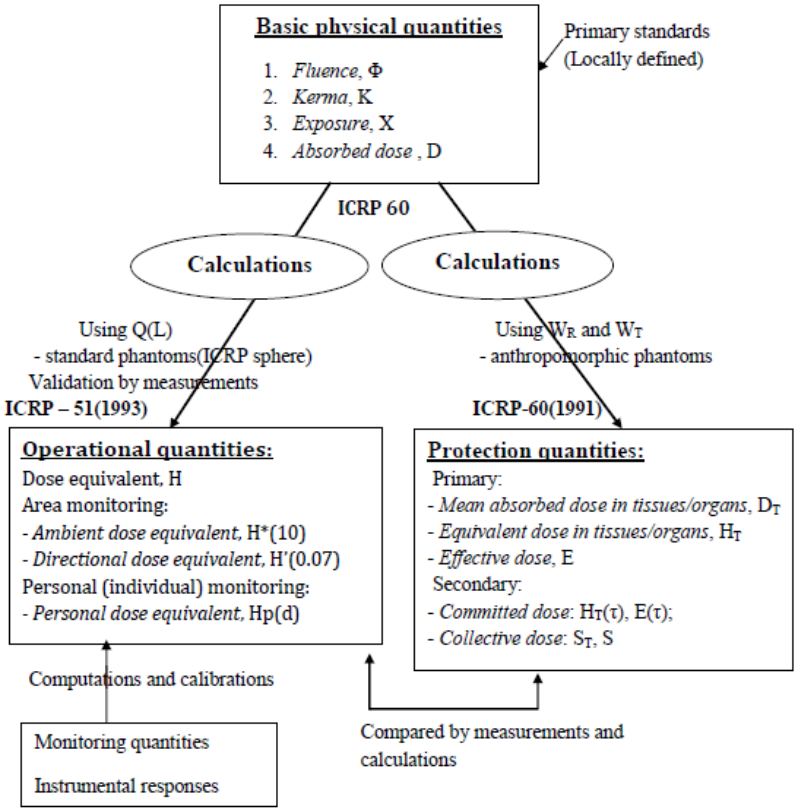
Physical and biological responses to ionizing radiation. Ionizing radiation causes damage either directly by damaging the molecular target or indirectly by ionizing water, which in turn generates free radicals that attack molecular targets. The physical steps that lead to energy deposition and free radical formation occur within 10^{-5} to 10^{-6} seconds, while the biological expression of the physical damage may occur seconds or decades later.

Time Frame for Effects of Ionizing Radiation

Times	Events
Physical stage	
$\lesssim 10^{-15}$ s	Formation of H_2O^+, H_2O^*, and subexcitation electrons, e^-, in local track regions ($\lesssim 0.1$ μm)
Prechemical stage	
$\sim 10^{-15}$ s to $\sim 10^{-12}$ s	Three initial species replaced by H_3O^+, OH, e_{aq}^-, H, and H_2
Chemical stage	
$\sim 10^{-12}$ s to $\sim 10^{-6}$ s	The four species H_3O^+, OH, e_{aq}^-, and H diffuse and either react with one another or become widely separated. Intratrack reactions essentially complete by $\sim 10^{-6}$ s
Biological stages	
$\lesssim 10^{-3}$ s	Radical reactions with biological molecules complete
$\lesssim 1$ s	Biochemical changes
Minutes	Cell division affected
Days	Gastrointestinal and central nervous system changes
Weeks	Lung fibrosis develops
Years	Cataracts and cancer may appear; genetic effects in offspring

Radiological protection and dosimetry – general remarks

Relationship between quantities used in radiological protection [2]



Basic physical quantities

- **Fluence** (particles/ cm²)

$$\Phi = \frac{dN}{da}$$

- **Kerma** (J/kg or Gray)

$$K = \frac{d\varepsilon_{tr}}{dm}$$

- **Exposure** (roentgen or C/kg)

$$X = \frac{dQ}{dm}$$

- **Absorbed dose** (J/kg or Gray)

$$D = \frac{d\varepsilon}{dm}$$

Protection quantities

- **Mean absorbed dose** (J/kg or Sievert)

$$D_T = \frac{\varepsilon_T}{m_T}$$

- **Equivalent dose in tissues/organs** (Sievert)

$$H_T = D_T \times w_R$$

- **Effective dose** (Sievert)

$$E = \sum_T w_T \times H_T = \sum_R w_R \times \sum_T w_T \times D_T$$

Protection quantities

Radiation weighting factors [3]

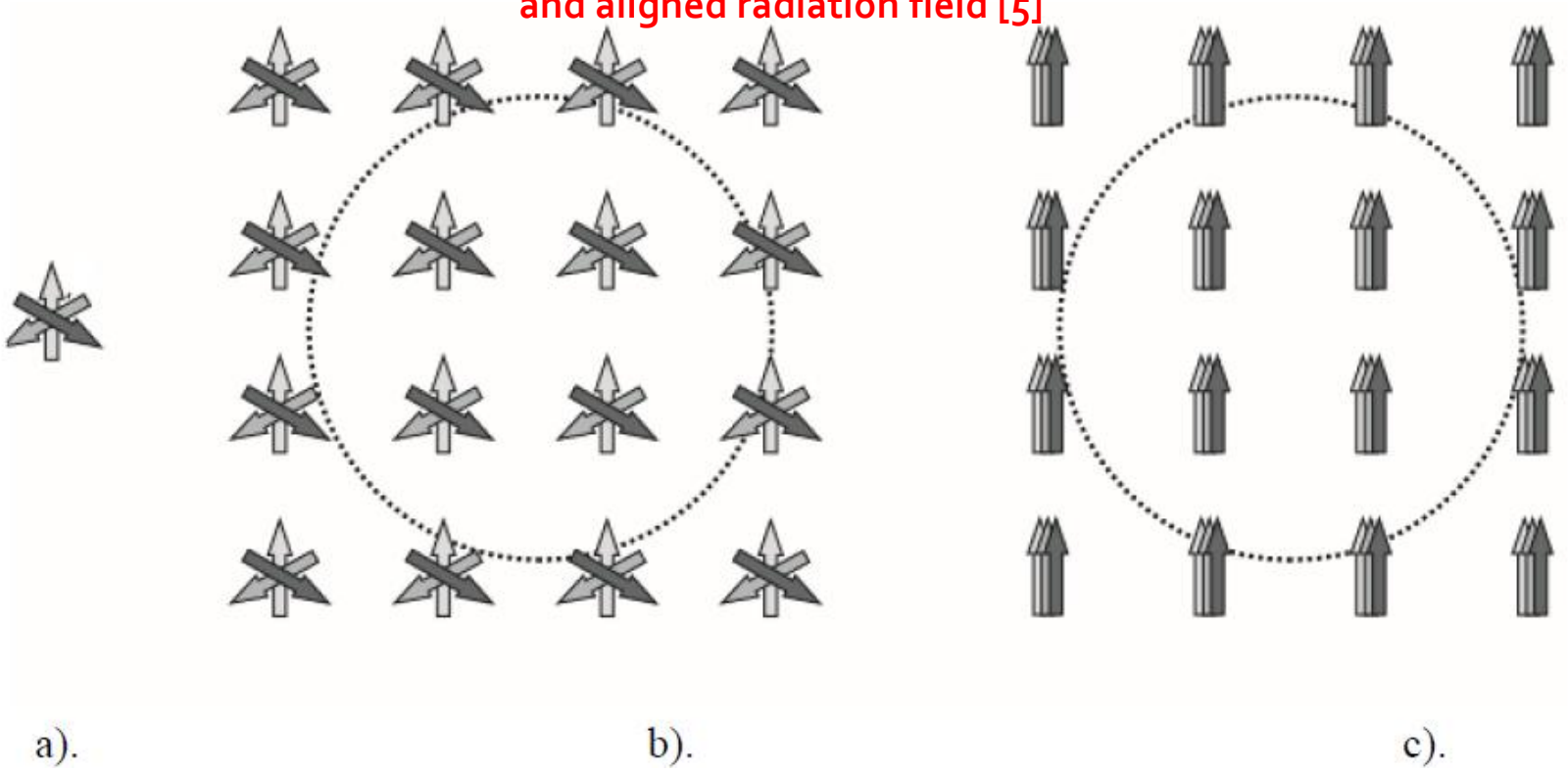
Type of radiation	Energy of radiation	Radiation weighting factor (w_R)
Photons	All energies	1
Electrons and muons	All energies	1
Neutrons	<10 keV	5
	10~100 keV	10
	>100 keV~2 MeV	20
	>2 MeV~20 MeV	10
	>20 MeV	5
Protons (except recoil protons)	>2 MeV	5
Alpha particles, fission fragments, heavy Nuclei	-	20

Tissue weighting factors [4]

Tissue/Organ	w_T
Bone marrow, colon, lung, stomach, breast, remainder*	0.12
Gonads	0.08
Bladder, liver, esophagus, thyroid	0.04
Bone surface, skin, brain, salivary glands	0.01

Operational quantities

Schematic representation of real radiation field in a point of reference compared with an expanded and aligned field. a) real radiation field, b) expanded radiation field, c) expanded and aligned radiation field [5]



Operational quantities

- Ambient dose equivalent, *H*(d)* (Sievert)

$$H^*(d) = Q(L) \times D$$

- Directional dose equivalent, H′(d, *Ω*) (Sievert)

- Personal dose equivalent, $H_P(d)$ (Sievert)

Conclusions

- I have studied the fundamental principles of radiological protection and dosimetry
- A set of dosimetry quantities used in radiological protection have been described and discussed
- Following my research I have gained an understanding of the meaning of assessing the risk following radiation exposure of the human body

References

- **[1]** "Biological effects of radiation and radiation protection" www.3nd.edu.com
- **[2]** S. Mattsson and C. Hoeschen (eds.), *Radiation Protection in Nuclear Medicine, DOI 10.1007/978-3-642-31167-3_2, © Springer-Verlag Berlin Heidelberg 2013*
- **[3]** International Commission on Radiation Units and Measurements, 1971, *Radiation quantities and units ICRU Report 19 (Bethesda, MD: ICRU), ICRU 1973 Dose equivalent Supplement to Report 19 (Bethesda, MD, USA: ICRU)*
- **[4]** ICRP, 2007. The 2007 Recommendations of the International Commission on Radiological Protection. ICRP Publication 103. Ann. ICRP 37 (2-4).
- **[5]** ALBERTS W.G., AMBROSI P., BOEHM J., DIETZE G., HOHFIELD K., WILL W., *New dose quantities in radiation protection, PTB-Dos-23EN (1995)*

The End

Thank you for your attention