Ionizing radiation, radiation protection

Kateřina Bradáčová

Content:

- types of ionizing radiation
- effects of ionizing radiation
- radiation protection

Ionizing radiation:

- energetic particles or waves that have the potential to ionize an atom or molecule through atomic interactions

Types of IR:

- particles current – (electrons, positrons, neutrons, alpha particles, …)
- gamma rays

Types of IR:

- α radiation – helium nucleus current
  - high ionizing efficiency
  - very short reach
    - in the air – 10 cm
    - in the tissues - 0,03 mm

Types of IR:

- β radiation – electron (β-) or positron (β+) current

  - more pentrating than α radiation

  - longer reach

    – in the tissues – a few mm

Types of IR:

- gamma rays – foton current
  - the highest penetration and reach

Source of IR:

- radioactive disintegration
- particle accelerators
- X-ray apparatus

Radioactive disintegration:

- alpha disintegration – strong nuclear repulsion

  - emitation of alpha particle (helium nucleus – 2 protons and 2 neutrons)

  - in general: $^{A}_{Z}X \rightarrow \, ^{A-4}_{Z-2}Y + \, ^{4}_{2}He\left(\alpha\right)$

  - e.g. $^{212}_{83}Bi \rightarrow \, ^{208}_{81}Tl + \, ^{4}_{2}He$

Radioactive disintegration:

- beta- disintegration – nucleus which has a lot of neutrons

  - in general: $\,{}^{A}_{Z}X \rightarrow {}^{A}_{Z+1}Y + \beta_{-} + \overline{\upsilon}_{e}$

  - e.g. $\,{}^{14}_{6}C \rightarrow {}^{14}_{7}N + \beta_{-} + \overline{\upsilon}_{e}$

Radioactive disintegration:

- beta+ disintegration – nucleus which has a lot of protons

  - in general: $^{A}_{Z}X \rightarrow \ ^{A}_{Z-1}Y + \beta_{+} + \overline{\upsilon}_{e}$

  - e.g. $^{11}_{6}C \rightarrow \ ^{11}_{5}B + \beta_{+} + \overline{\upsilon}_{e}$

Radioactive disintegration:

- heavy nucleus disintegration – produces two daughter nucleuses and several neutrons

- in general: $^{A}_{Z}X \rightarrow \; ^{A1}_{Z1}Y_1 + \; ^{A2}_{Z2}Y_2 + i \; ^{1}_{0}n$

Particle accelerators:

- linear
- betatron (accelerate electrons which strike on the metalic target → X-rays)
- cyclotron (to make radionuclides and neutron current)

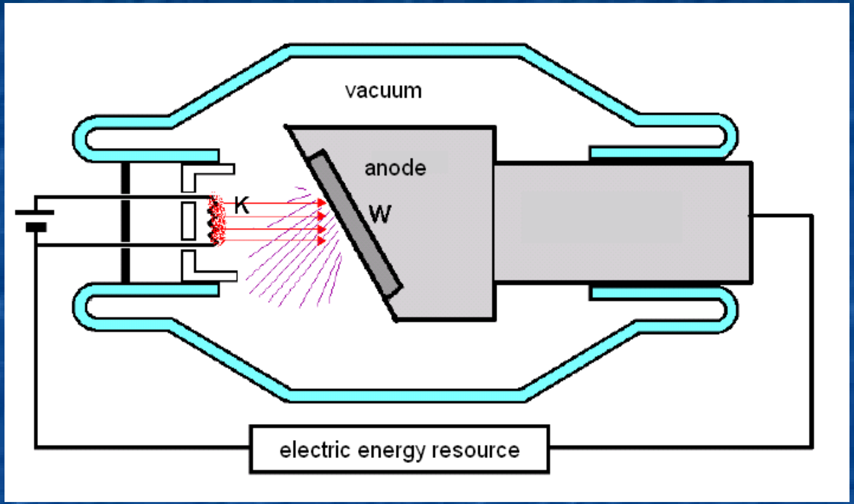
X-ray apparatus:

- skiagraphy
- fluoroscopy
- skiagraph-fluoroscopy
- CT
- angiography
- mamography

X-ray apparatus:

- X-ray tube
- electrical energy resource
- examination table
- control panel
- image amplifier

X-ray tube:



- high energy electrons are emited from catode and strike on the metalic anode

Bremsstrahlung radiation– electrons are stopped by repulsive force of electrons in electron shell. Kinetic energy of electons is changed into energy of X-ray photons

Characteristic X-ray – electrons dash out the electrons of K or L shells. Than the vacant site is filled by electrons from a higher energy shell.

X-ray tube:

- speed of electrons - about 165 000 km/s (voltage 100 kV)
- higher voltage → higher kinetic energy of electrons → shorter wave lenghth
- vawe lenghth – 1pm – 10nm

Filtration and shades:

Filtration – reduces intensity of low energy X-ray, reduces irradiation of skin and hypodermis

- Al, Cu
- self-filtration, supplementary filtration

Filtration and shades:

Secundary (Bucky´s) shade – absorbs secundary and scattered radiation

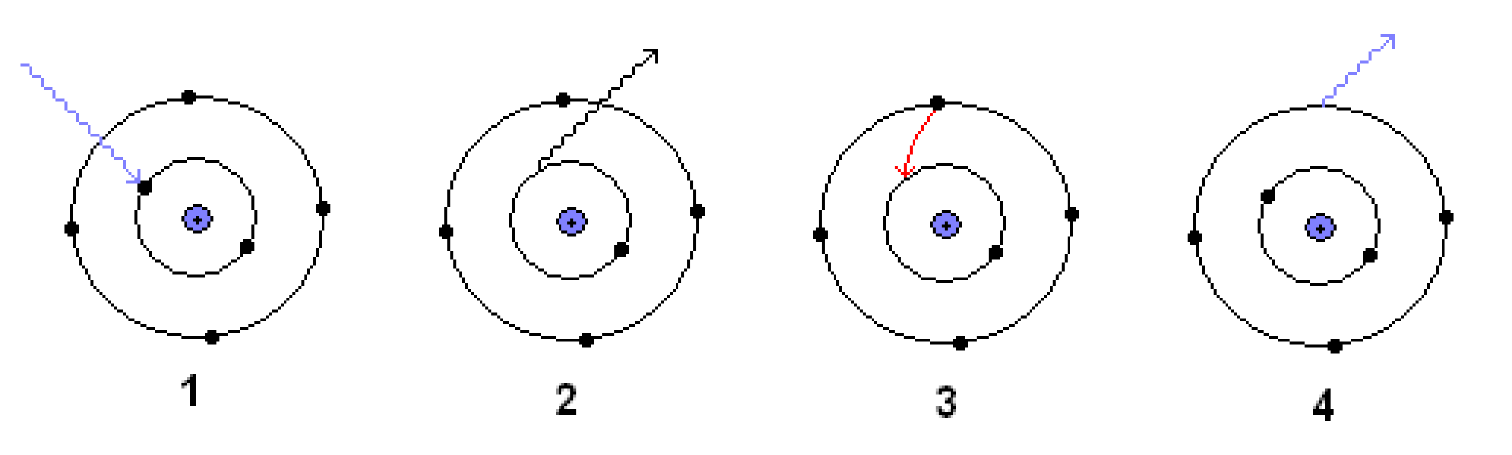
- from lead belts

Effects of ionizing radiation

Interaction of IR with matter:

- gamma rays – ionize by secondary electrons which are caused by this processes:

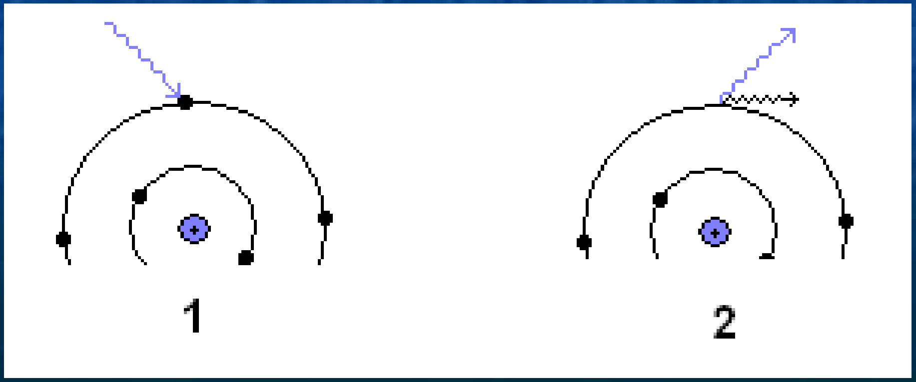
Photoelectric effect – electrons are emitted from the atom after the absorption of energy from X-ray



Interaction of IR with matter:

- gamma rays – ionize by secondary electrons which are caused by this processes:

Compton effect – in the electron being given part of the energy and a photon containing the remaining energy being emitted in a different direction from the original. If the photon still has enough energy, the process may be repeated. If the photon has sufficient energy it can even eject an electron from its host atom entirely (Photoelectric effect).



Interaction of IR with matter:

- gamma rays – ionize by secondary electrons which are caused by this processes:

Pair production - a high-energy photon interacts with an atomic nucleus, allowing it to produce an electron and a positron

Interaction of IR with matter:

- particles current – the energy of particle is changed $\rightarrow$ secondary radiation

  - primary and secondary radiation ionize atoms and molecules

α radiation – high ionizing efficiency

β- radiation – used in therapy

β+ radiation – used in PET

neutron current – used in therapy

Biological effects of IR:

- it is known 4 terms of biological effects of IR

physical term – takes 10^{-16}-10^{-14} s

- energy of photons is handed on electrons, it causes ionization and excitation of atoms

phisiochemical term – takes 10^{-14}-10^{-10}s

- interaction of ions with molecules, dissociation of molecules, occurance of radicals

Biological effects of IR:

- it is known 4 terms of biological effects of IR

chemical term – takes 0,001 – 1 s

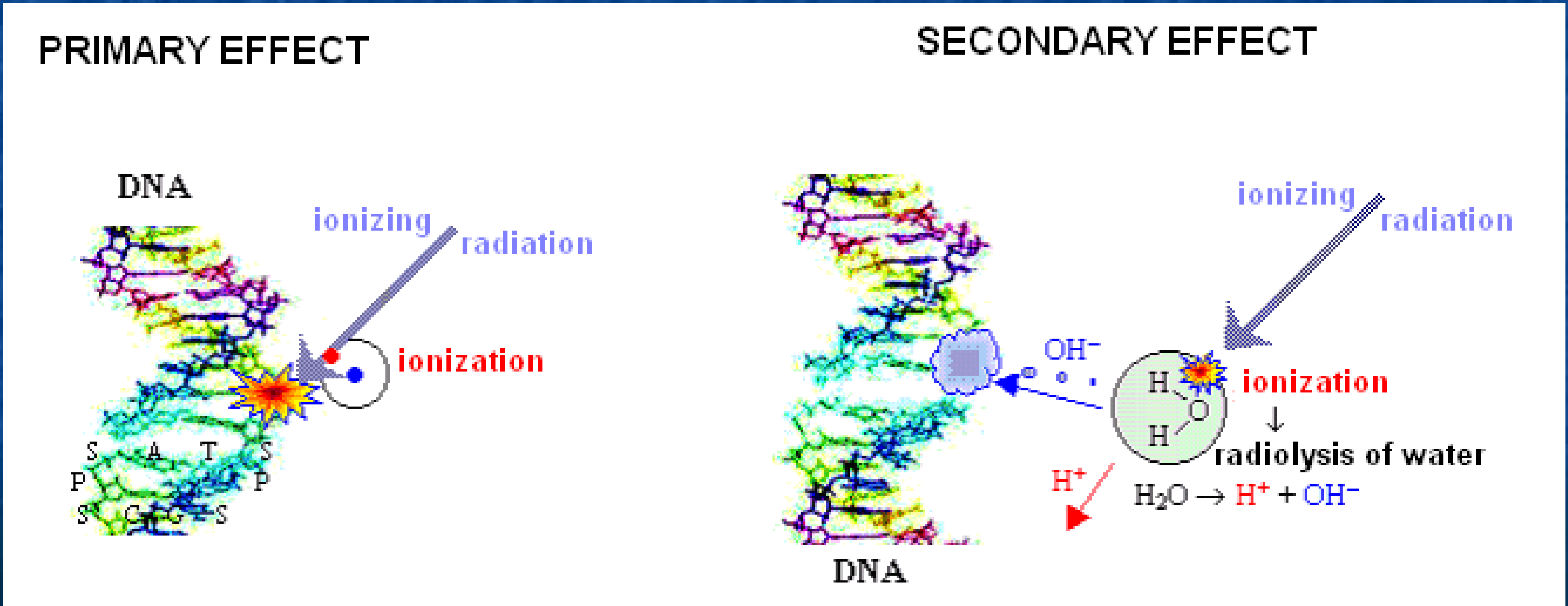
- interaction of ions, radicals, excited atoms with biological organic molecules (DNA, proteins)

biological term – takes a few minutes – tens years

- functional and morfological changes in cells, organs and whole organism

DNA damage:

- DNA breakes (singlestrand, doublesrand), interstrand cross-links



Cell damage:

- <u>cell death</u>

  mitotic – cell cannot segment (smaller irradiation)

  in interphase – damage of cell components (higher irradiation)

Cells with high segmentation ability are much more radiosensitive!!!

- <u>mutation</u> – changes in DNA and chromozomes (gene, chromozomal, somatic X gametic)

Reparation of:

- cells

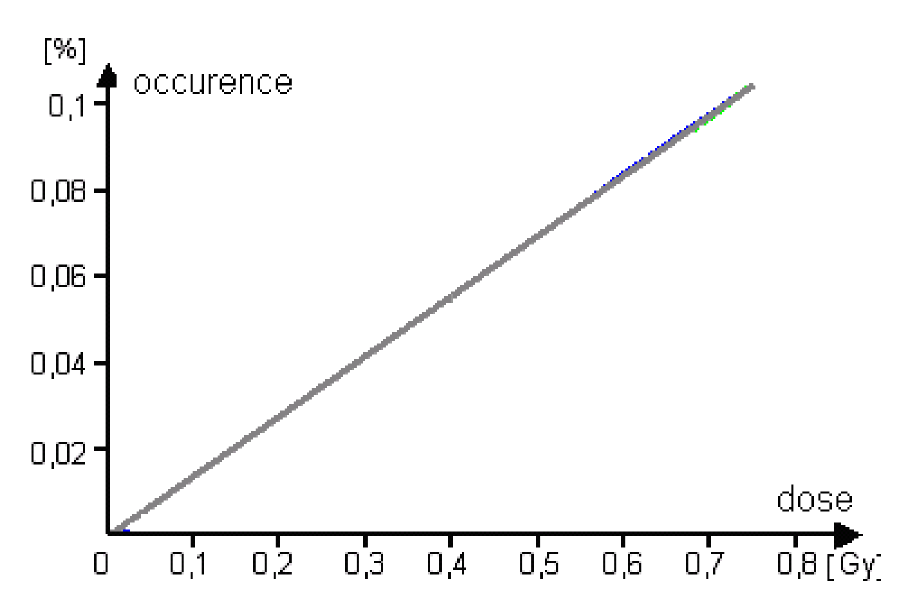
- reparation of DNA structure, excision of inreparable DNA segments

- tissues

- supplying damaged cells by segmentation of surviving cells

Biological effects of IR:

- stochastic
  - severity is independent of absorbed dose
  - threshold does not exist
  - probability of occurrence depends on absorbed dose
  - example: cancer, genetic effect



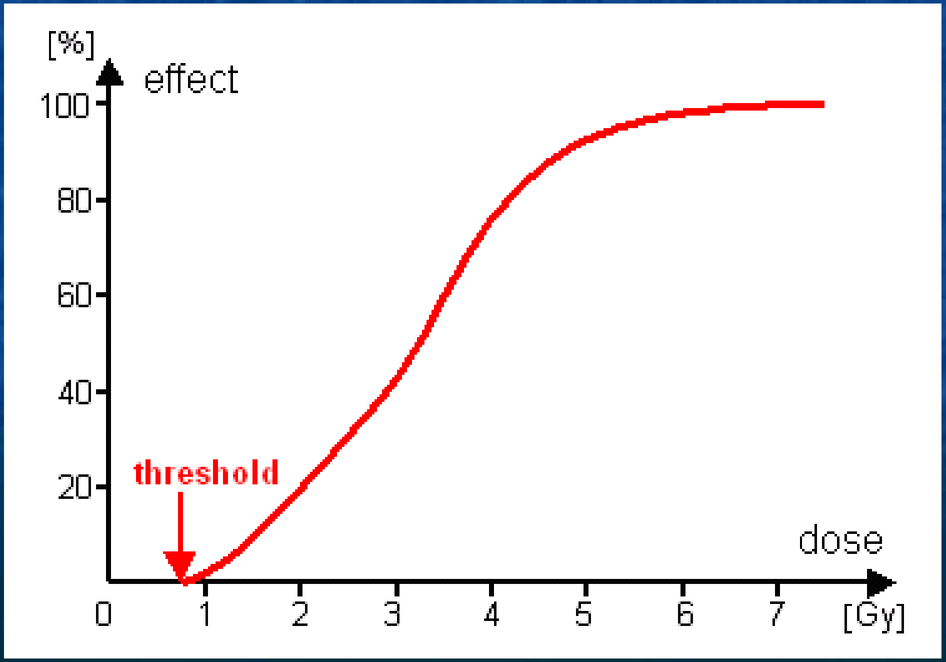
Biological effects of IR:

- deterministic

  - damage depends on absorbed dose

  - threshold exists

  - example: cataract, erythema, infertility etc



Deterministic effects:

- accute radiation syndrome

bone marrow form - threshold 1-2Gy (typical 3-6Gy)

- massive loss of leukocytes, greatly increasing the risk of infection
- uncontrollable bleeding in the mouth, under the skin and in the kidneys
- bone marrow is nearly or completely destroyed, so a bone marrow transplant is required

gastric form – dose 6-10Gy

- gastric and intestinal tissue are severely damaged
- nausea, vomiting, diarrhoea (loss of minerals and water)

Deterministic effects:

- accute radiation syndrome

  cardiovascular form - dose 20Gy

  - arrythmia, heart failure

  neuropsychic form - dose 40Gy

  - apatia, letargia, psychic alteration, inactivation of chemical receptors in the brain

- infertility
- cataract - dose 4-8 Gy
- acute radiation dermatitis (erythema, loss of hair all over the body, blisters and ulcers, necrosis)

Effects to embryo and foetus:

- embryo and foetus are very sensitive to IR
- damage depends on the dose and the stage of development

- first 2 weeks – „all or nothing“
- 3.–8. week (organogenesis) – risk of malformation
- 8.-15. week – risk of mental handicap
- since 15. week – relative resistance (like a newborn)

Radiation protection

Dosimetric magnitudes:

- express quantity of effects of ionizing radiation to matter (tissue, patient)

Dosimetric magnitudes

- absorbed dose – energy which ionizing radiation hands on the matter with unit of weight
  - Gray (Gy)
- kerma – energy which primary ionizing radiation hands on the matter with unit of weight
  - Gray (Gy)
- effective dose – expresses effects with regard to irradiation of various parts of body
  - Sievert (Sv)

Radiosensitivity of various types of tissues and organum

- gonads
- bone marrow, colon, stomach, lungs
- breast, urinary bladder, thyroid, liver, oesophagus
- skin, bones

.

.

.

- muscles, brain

Sources of IR:

	Source of radiation	Effective dose [mSv/ year]	[%]	
Natural	Radon	1,3	48	88%
	Terrestrial radiation	0,45	17	
	Irradiation by radionuclides in body	0,25	9	
	Cosmic radiation	0,4	14	
---	--	------------	----	-----
Made	Medical radiation (diagnostic, therapeutical)	0,3	11	12%
	Professional radiation	0,002	0,08	
	Technical appliances	0,005	0,02	
	Nuclear energetics	0,001	0,04	
	Radioactive fall (nuclear weapons, incidents)	0,005	0,02	

Legislation:

- EUROATOM (law 18/1997)
  - aim of radiation protection (elimination of deterministic effects, minimalisation stochastic effects)
  - principle of working with IR (reasons for working, optimalisation, limitation)
- public notices of SÚJB (184/1997, 146/1997, 214/1997, 307/2002)

Limits for workers with IR:

- 50 mSv / year
- 100 mSv / 5 years
- 150 mSv for lens / year
- 500 mSv for 1 cm^2 of skin / year
- 500 mSv for limbs / year

Categories of workplaces:

- 1st category – small sources, denzitometry, dental X-ray
- 2nd category – radiodiagnostics, therapy
- 3rd category – particle accelerators
- 4th category – nuclear power station, disposal site of nuslear waste

Radiation protection:

- physical

  time - work as quickly as possible

  distance – by doubling the distance the dose rate is quartered

  shielding - α radiation - clothes, paper, plexiglass

  β radiation – plexiglass or aluminum

  γ rays – lead, steel, baryum concrete

  neutron radiation – materials containing a lot of hydrogen, cadmium and boron

- chemical - radioprotective substances

- biological – improving the immunity

Protection of workers with IR:

- personal dosimetry

  - measure an absolute dose received over a period of time

  - by personal dosimetres

dozimetres: film, termoluminescent,
scintilation, electrical,
chemical

Protection of patients:

- Principle 1: reasons of medical irradiation

  - risk of the radiation damage must be less than a benefit for the patient

- Principle 2: optimalization

  - it is needed to aplicate the minimal necessary quantity of radiation which guarantees the quality of radiogram

Protection of patients:

- Was the examination done?
- Do you necessary need this examinaton?
- Do you need the examination now?
- Is it the best type of examination?

Effective doses of X-ray examinations:

Type of examination	Typical effective dose (mSv)	Time to stay in natural background radiation
Radiogram of skull	0,07	10 days
R. of Th spine	0,7	3,5 months
R. of L spine	1,3	6 months
R. of chest	0,02	3 days
R. of abdomen	1	5 months
R. of pelvis	0,7	3,5 months
R. of hip joint	0,3	1,5 months
R. of limb	0,01	1,5 days
urography	2,5	1 year
Fluoroscopy of stomach	3	1,2 years
Fluoroscopy of colon	3	1,2 years
irrigoscopy	7	2,8 years
CT of head	2,3	11 months
CT of chest	8	3,2 years
CT of abdomen or pelvis	10	4 years

Effective doses of examination in NM:

Type of examination	Typical effective dose (mSv)	Time to stay in natural background radiation
Static scitigraphy of kidneys	1,5	7 months
Dynamic scintigraphy of kidneys	2,2	10,5 months
Dynamic cholescintigraphy	2,3	11 months
Scintigraphy of skeleton	3,4	16 months
Perfused scintigraphy of lungs	1,2	6 months
Scintigraphy of thyroid	2,2	10,5 months
Scintigraphy of myocardium	7,5	3 years