ODESSA NATIONAL MEDICAL UNIVERSITY

Department of Radiation Diagnostics, Therapy, radiation medicine and Oncology

METHODICAL RECOMMENDATIONS FOR STUDYING THE TOPIC:

"Biological action of ionizing radiation. Radioactivity and dose. Dosimetry of ionizing radiation. Principles and methods of radiation therapy in dentistry".

(for the 3th year students of the dentistry faculty)

Approved
at the methodical meeting of the department
"27" August 2021
Protocol №1
Head Department ________ Sokolov V.M.

ODESSA- 2021

« Biological action of ionizing radiation. Radioactivity and dose. Dosimetry of ionizing radiation. Principles and methods of radiation therapy in dentistry» - 2 hours.

1. Actuality of theme:

Knowledge of the physical basis of ionizing radiation, its types, units of measurement and method of determining the dose, structure of radiometers and dosimeters, the physical principles on which they work, are necessary for specialists in any field of medical activity. The relevance of this topic is due to its importance for the study of a number of subsequent topics in radiology, radiation medicine, hospital therapy. Therefore, the main goals and objectives of training are related to the formation of professional knowledge and skills for deontology, ecology, legal and psychological activities in medicine.

2. Educational aims:

2.1. General goals:

Educational goals are related to the formation of the future doctor's responsibility for the correct assessment of effective and equivalent doses; be able to explain to the patient the need for protection against radioactivity and methods of protection depending on different types of radiation.

2.3. Specific goals:

- to know:

1. Analyze and have an idea of the basic properties of ionizing radiation, units and methods for determining the radiation dose, the structure of radiometers and dosimeters.
2. Explain the basic properties of ionizing radiation and their possibilities for use in medicine.

2.4. Based on theoretical knowledge on the topic:

- master the techniques / be able /:

1.Be able to estimate and calculate the absorbed, exposure, equivalent, lethal, threshold, population doses.
2. It is correct to choose ways and methods of protection against the main types of ionizing radiation under different conditions.
3. Justify the use of a dosimeter or radiometer in different conditions.
4. Classify methods and techniques of protection against the main types of ionizing radiation.

5. Analyze the relevant clinical objectives, evaluate and calculate the absorbed, exposure, equivalent, lethal, threshold, population doses.

3. Materials for classroom independent training (interdisciplinary integration).

№№ п.п.	**Names of previous disciplines**	**Acquired knowledge and skills**	**Be able**
1	**2**	**3**	**4**
I.	Previous disciplines 1. Physics 2. Physiology 3. Pathological physiology.	The structure of the atom Cell homeostasis Changes in the cell under the influence of radiation	
II.	The following disciplines 1. Radiation medicine 2. Hospital therapy	Justify the use of a dosimeter or radiometer in different conditions. It is correct to choose ways and methods of protection against the main types of ionizing radiation.	
III.	Intra-subject integration 1. Dosimetry 2. Methods of dosimetry.	Use the main types of radiometers and dosimeters.	

4. Topic content (text or theses), graph of the logical structure of the lesson.

Basic Terms Radiation.Radiation is energy in transit in the form of high-speed particles and electromagnetic waves. We encounter electromagnetic waves every day. They make up our visible light, radio and television waves, ultra violet (UV), and microwaves with a large spectrum of energies. These examples of electromagnetic waves do not cause ionizations of atoms because they do not carry enough energy to separate molecules or remove electrons from atoms.

Ionizing radiation Ionizing radiation is radiation with enough energy so that during an interaction with an atom, it can remove tightly bound electrons from their orbits, causing the atom to become charged or ionized. Examples are gamma rays and neutrons.

Non-ionizing radiation is radiation without enough energy to remove tightly bound electrons from their orbits around atoms. Examples are microwaves and visible light.

Health Physics is an interdisciplinary science and its application, for the radiation protection of humans and the environment. Health Physics combines the elements of physics, biology, chemistry, statistics and electronic instrumentation to provide information that can be used to protect individuals from the effects of radiation. For more on Health Physics, visit the career section of the Health Physics Society. X

Radioactivity is the spontaneous transformation of an unstable atom and often results in the emission of radiation. This process is referred to as a transformation, a decay or a disintegration of an atom.

Radioactive Material is any material that contains radioactive atoms.

Radioactive contamination is radioactive material distributed over some area, equipment or person. It tends to be unwanted in the location where it is, and has to be cleaned up or decontaminated.

Common Types of Radiation

Gamma rays are electromagnetic waves or photons emitted from the nucleus (center) of an atom.

Betas. A beta is a high-speed particle, identical to an electron, that is emitted from the nucleus of an atom

Alphas. An alpha is a particle emitted from the nucleus of an atom, that contains two protons and two neutrons. It is identical to the nucleus of a Helium atom, without the electrons.

Neutrons are neutral particles that are normally contained in the nucleus of all atoms and may be removed by various interactions or processes like collision and fission

X Rays are electromagnetic waves or photons not emitted from the nucleus, but normally emitted by energy changes in electrons. These energy changes are either in electron orbital shells that surround an atom or in the process of slowing down such as in an X-ray machine.

Common Units – USA. These are the common units used in the United States in health physics. **Roentgen (R).** The roentgen is a unit used to measure a quantity called exposure. This can only be used to describe an amount of gamma and X-rays, and only in air. One roentgen is equal to depositing in dry air enough energy to cause 2.58E-4 coulombs per kg. It is a measure of the ionizations of the molecules in a mass of air. The main advantage of this unit is that it is easy to measure directly, but it is limited because it is only for deposition in air, and only for gamma and x rays.

Rad (radiation absorbed dose). The rad is a unit used to measure a quantity called absorbed dose. This relates to the amount of energy actually absorbed in some material, and is used for any type of radiation and any material. One rad is defined as the absorption of 100 ergs per gram of material. The unit rad can be used for any type of radiation, but it does not describe the biological effects of the different radiations.

Rem (roentgen equivalent man). The rem is a unit used to derive a quantity called equivalent dose. This relates the absorbed dose in human tissue to the effective biological damage of the radiation. Not all radiation has the same biological effect, even for the same amount of absorbed dose. Equivalent dose is often expressed in terms of thousandths of a rem, or mrem. To determine equivalent dose (rem), you multiply absorbed dose (rad) by a quality factor (Q) that is unique to the type of incident radiation.

Curie (Ci). The curie is a unit used to measure a radioactivity. One curie is that quantity of a radioactive material that will have 37,000,000,000 transformations in one second. Often radioactivity is expressed in smaller units like: thousandths (mCi), one millionths (uCi) or even billionths (nCi) of a curie. The relationship between becquerels and curies is: 3.7×10^{10} Bq in one curie.

Common Units - SI - International Standard. Note: These are the common units used throughout the world in health physics.

Gray (Gy). The gray is a unit used to measure a quantity called absorbed dose. This relates to the amount of energy actually absorbed in some material, and is used for any type of radiation and any material. One gray is equal to one joule of energy deposited in one kg of a material. The unit gray can be used for any type of radiation, but it does not describe the biological effects of the different radiations. Absorbed dose is often expressed in terms of hundredths of a gray, or centi-grays. One gray is equivalent to 100 rads.

Sievert (Sv). The sievert is a unit used to derive a quantity called equivalent dose. This relates the absorbed dose in human tissue to the effective biological damage of the radiation. Not all radiation has the same biological effect, even for the same amount of absorbed dose. Equivalent dose is often expressed in terms of millionths of a sievert, or micro-sievert. To determine equivalent dose (Sv), you multiply absorbed dose (Gy) by a quality factor (Q) that is unique to the type of incident radiation. One sievert is equivalent to 100 rem.

Becquerel (Bq). The Becquerel is a unit used to measure a radioactivity. One Becquerel is that quantity of a radioactive material that will have 1 transformations in one second. Often radioactivity is expressed in larger units like: thousands (kBq), one millions (MBq) or even billions (GBq) of a becquerels. As a result of having one Becquerel being equal to one transformation per second, there are 3.7×10^{10} Bq in one curie.

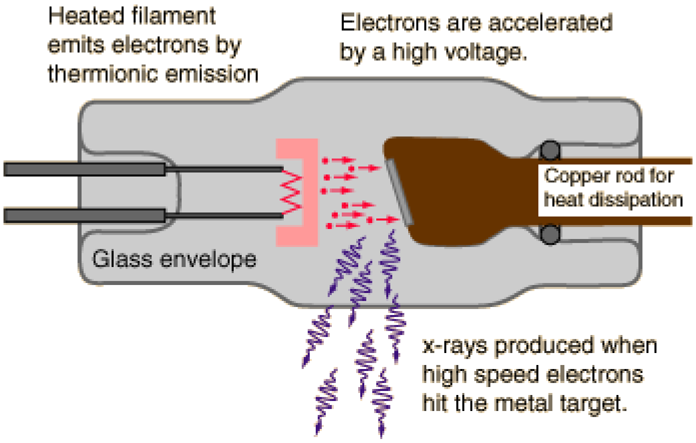
SI Prefixe. Many units are broken down into smaller units or expressed as multiples, using standard metric prefixes. As examples, a kilobecquerel (kBq) in 1000 becquerels, a millirad (mrad) is 10^{-3} rad, a microrem (µrem) is 10^{-6} rem, a nanogram is 10^{-9} grams, and a picocurie is a 10^{-12} curies.

SI Prefixes						
Factor	**Prefix**	**Symbols**		**Factor**	**Prefix**	**Symbols**
10^{18}	exa	E		**10^{-1}**	deci	d
10^{15}	peta	P		**10^{-2}**	centi	c
10^{12}	tera	T		**10^{-3}**	milli	m
10^{9}	giga	G		**10^{-6}**	micro	µ
10^{6}	mega	M		**10^{-9}**	nano	n
10^{3}	kilo	k		**10^{-12}**	pico	p
10^{2}	hecto	h		**10^{-15}**	femto	f
10^{1}	deka	da		**10^{-18}**	atto	a

Terms Related to Radiation Dose

A Chronic dose means a person received a radiation dose over a long period of time.**An acute dose** means a person received a radiation dose over a short period of time.**Somatic effects** are effects from some agent, like radiation that are seen in the individual who receives the agent.**Genetic effects** are effects from some agent, that are seen in the offspring of the individual who received the agent. The agent must be encountered pre-conception.**Teratogenic effects** are effects from some agent, that are seen in the offspring of the individual who received the agent. The agent must be encountered during the gestation period.**Stochastic effects** are effects that occur on a random basis with its effect being independent of the size of dose. The effect typically has no threshold and is based on probabilities, with the chances of seeing the effect increasing with dose. Cancer is a stochastic effect. **Non-stochastic effects** are effects that can be related directly to the dose received. The effect is more severe with a higher dose, i.e., the burn gets worse as dose increases. It typically has a threshold, below which the effect will not occur. A skin burn from radiation is a non-stochastic effect.

X-ray Tube	Index



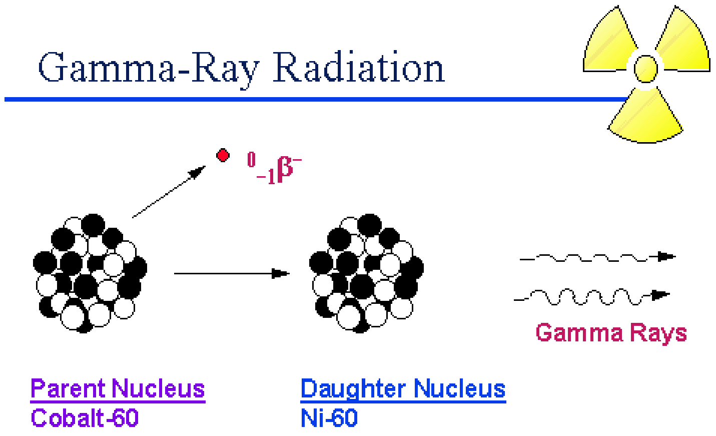
X-rays for medical diagnostic procedures or for research purposes are produced in a standard way: by accelerating electrons with a high voltage and allowing them to collide with a metal target. X-rays are produced when the electrons are suddenly decelerated upon collision with the metal target; these x-rays are commonly called brehmsstrahlung or "braking radiation". If the bombarding electrons have sufficient energy, they can knock an electron out of an inner shell of the target metal atoms. Then electrons from higher states drop down to fill the vacancy, emitting x-ray photons with precise energies determined by the electron energy levels. These x-rays are called characteristic x-rays. X

Characteristic x-rays	Brehmsstrahlung

HyperPhysics***** Quantum Physics Go Back

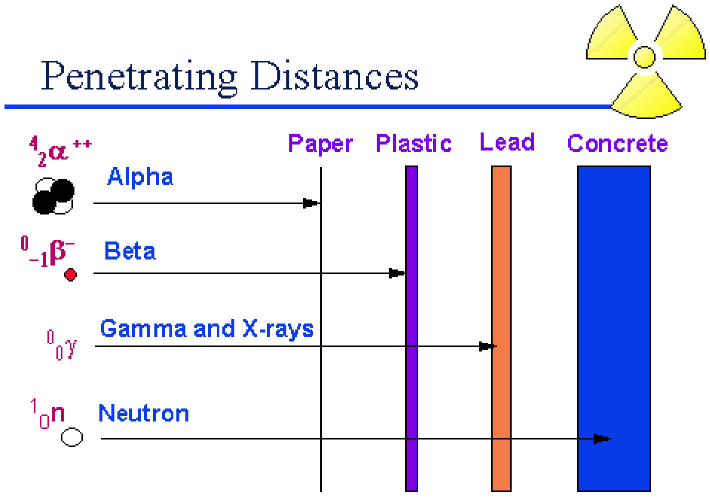
Electromagnetic Spectrum Quiz

Gamma Radiation



X

After a decay reaction, the nucleus is often in an “excited” state. This means that the decay has resulted in producing a nucleus which still has excess energy to get rid of. Rather than emitting another beta or alpha particle, this energy is lost by emitting a pulse of electromagnetic radiation called a gamma ray. The gamma ray is identical in nature to light or microwaves, but of very high energy.
Like all forms of electromagnetic radiation, the gamma ray has no mass and no charge. Gamma rays interact with material by colliding with the electrons in the shells of atoms. They lose their energy slowly in material, being able to travel significant distances before stopping. Depending on their initial energy, gamma rays can travel from 1 to hundreds of meters in air and can easily go right through people. It is important to note that most alpha and beta emitters also emit gamma rays as part of their decay process. However, their is no such thing as a “pure” gamma emitter. Important gamma emitters including technetium-99^{m} which is used in nuclear medicine, and cesium-137 which is used for calibration of nuclear instruments.



X

In summary, the most common types of radiation include alpha particles, beta and positron particles, gamma and x-rays, and neutrons. Alpha particles are heavy and doubly charged which cause them to lose their energy very quickly in matter. They can be shielded by a sheet of paper or the surface layer of our skin. Alpha particles are only considered hazardous to a person's health if an alpha emitting material is ingested or inhaled. Beta and positron particles are much smaller and only have one charge, which cause them to interact more slowly with material. They are effectively shielded by thin layers of metal or plastic and are again only considered hazardous if a beta emitter is ingested or inhaled.

Gamma emitters are associated with alpha, beta, and positron decay. X-Rays are produced either when electrons change orbits within an atom, or electrons from an external source are deflected around the nucleus of an atom. Both are forms of high energy electromagnetic radiation which interact lightly with matter. X-rays and gamma rays are best shielded by thick layers of lead or other dense material and are hazardous to people when they are external to the body.

Neutrons are neutral particles with approximately the same mass as a proton. Because they are neutral they react only weakly with material. They are an external hazard best shielded by thick layers of concrete. Neutron radiation will be discussed in more detail in the discussion of nuclear power.

Properties of Radiation

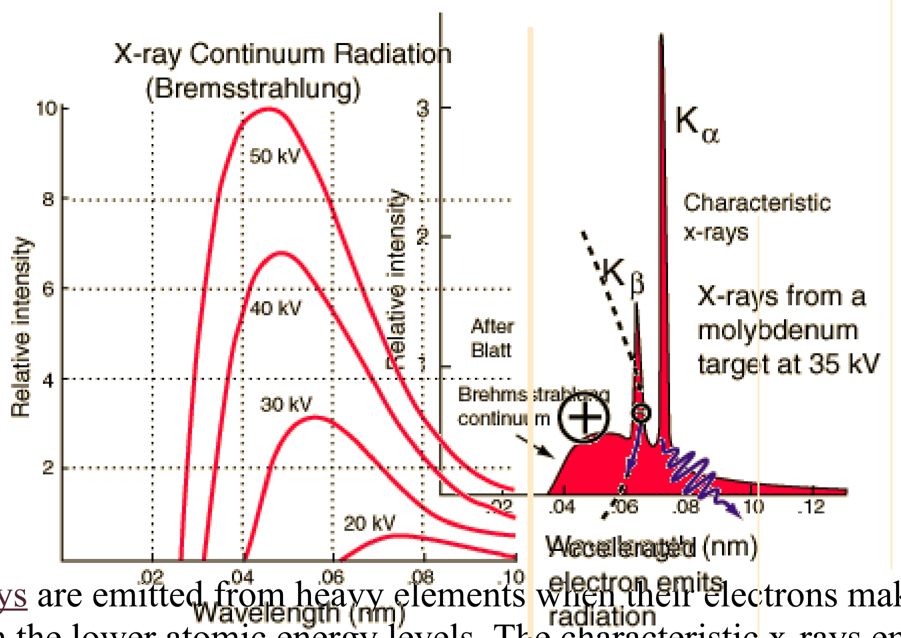
Different radiations have different properties, as summarized below:

Radiation	Type of Radiation	Mass (AMU)	Charge	Shielding material
Alpha	Particle	4	+2	Paper, skin, clothes
Beta	Particle	1/1836	±1	Plastic, glass, light metals
Gamma	Electromagnetic Wave	0	0	Dense metal, concrete, Earth
Neutrons	Particle	1	0	Water, concrete, polyethylene, oil

ray Tube FAQ Page

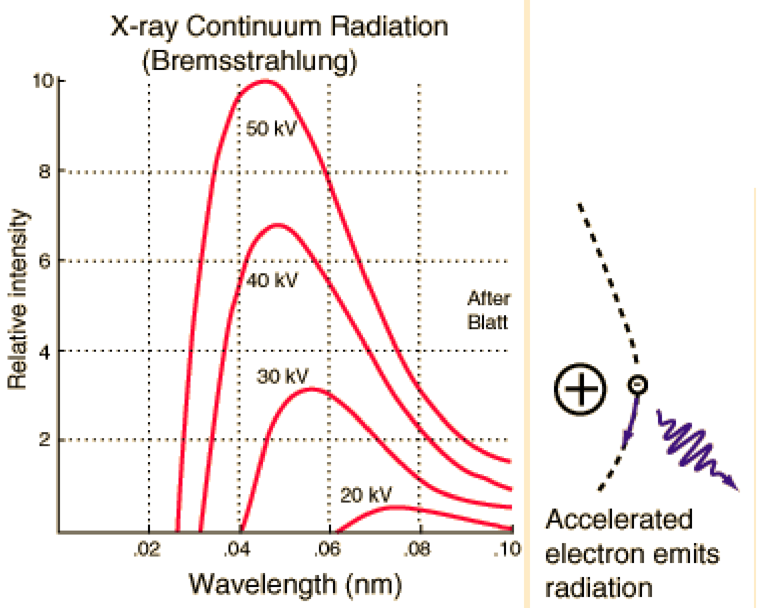
This page is meant as a general information page for people that would like some information on the x-ray tube and its components and the physics that apply to stationary anode x-ray tubes. It is intended to present these ideas in terms everyone can understand, while still being useful to professionals in the field. This may make this discussion overly simplistic for some of you and overly complex for others. We hope that you find this page useful. For links to other x-ray related information please visit our links page. If you have specific questions about the physics that apply to stationary anode x-ray tubes or questions of a more advanced nature please contact engineering.. Please direct questions, comments, or suggestions regarding this website to the webmaster.

Characteristic X-Rays



Characteristic x-rays are emitted from heavy elements when their electrons make transitions between the lower atomic energy levels. The characteristic x-rays emission which shown as two sharp peaks in the illustration at left occur when vacancies are produced in the n=1 or K-shell of the atom and electrons drop down from above to fill the gap. The x-rays produced by transitions from the n=2 to n=1 levels are called K-alpha x-rays, and those for the n=3->1 transiton are called K-beta x-rays. X
Transitions to the n=2 or L-shell are designated as L x-rays (n=3->2 is L-alpha, n=4->2 is L-beta, etc.). The continuous distribution of x-rays which forms the base for the two sharp peaks at left is called "bremsstrahlung" radiation. X
X-ray production typically involves bombarding a metal target in an x-ray tube with high speed electrons which have been accelerated by tens to hundreds of kilovolts of potential. The bombarding electrons can eject electrons from the inner shells of the atoms of the metal target. Those vacancies will be quickly filled by electrons dropping down from higher levels, emitting x-rays with sharply defined frequencies associated with the difference between the atomic energy levels of the target atoms. X
The frequencies of the characteristic x-rays can be predicted from the Bohr model. Moseley measured the frequencies of the characteristic x-rays from a large fraction of the elements of the periodic table and produces a plot of them which is now called a "Moseley plot". X
Characteristic x-rays are used for the investigation of crystal structure by x-ray diffraction. Crystal lattice dimensions may be determined with the use of Bragg's law in a Bragg spectrometer. X

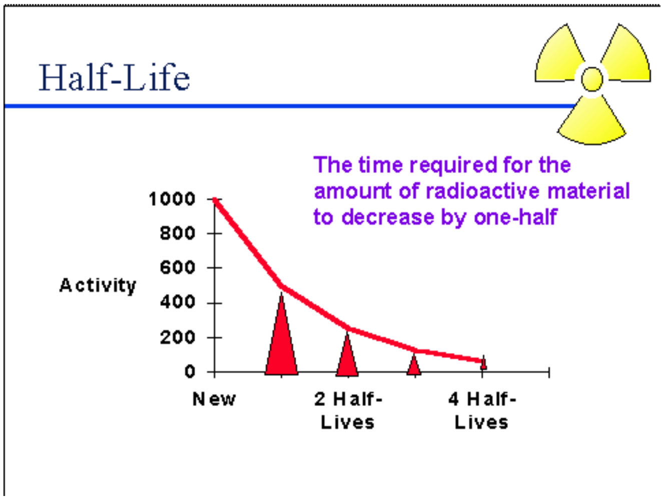
Bremsstrahlung X-Rays



"Bremsstrahlung" means "braking radiation" and is retained from the original German to describe the radiation which is emitted when electrons are decelerated or "braked" when they are fired at a metal target. Accelerated charges give off electromagnetic radiation, and when the energy of the bombarding electrons is high enough, that radiation is in the x-ray region of the electromagnetic spectrum. It is characterized by a continuous distribution of radiation which becomes more intense and shifts toward higher frequencies when the energy of the bombarding electrons is increased. The curves above are from the 1918 data of Ulrey, who bombarded tungsten targets with electrons of four different energies.X

The bombarding electrons can also eject electrons from the inner shells of the atoms of the metal target, and the quick filling of those vacancies by electrons dropping down from higher levels gives rise to sharply defined characteristic x-rays. X

Half-life



Half-Life

The time required for the amount of radioactive material to decrease by one-half

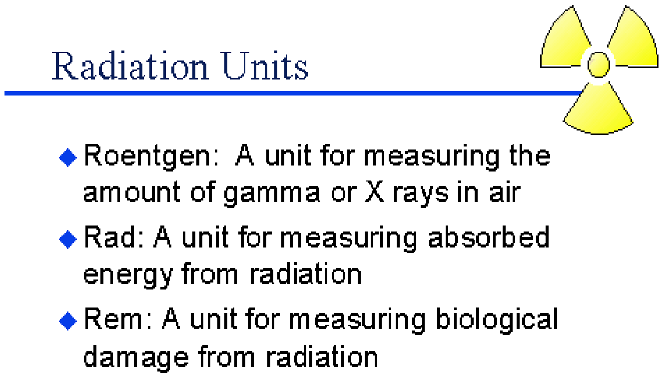
Half-life is the time required for the quantity of a radioactive material to be reduced to one-half its original value.

All radionuclides have a particular half-life, some of which a very long, while other are extremely short. For example, uranium-238 has such a long half life, $4.5x10^9$ years, that only a small fraction has decayed since the earth was formed. In contrast, carbon-11 has a half-life of only 20 minutes. Since this nuclide has medical applications, it has to be created where it is being used so that enough will be present to conduct medical studies. Here is a on-line calculator that will calculate the activity of some radionuclides at some time after it is formed.X

Radiation Measurement. When given a certain amount of radioactive material, it is customary to refer to the quantity based on its activity rather than its mass. The activity is simply the number of disintegrations or transformations the quantity of material undergoes in a given period of time.

The two most common units of activity are the Curie and the Becquerel. The Curie is named after Pierre Curie for his and his wife Marie's discovery of radium. One Curie is equal to $3.7x10^{10}$ disintegrations per second. A newer unit of activity if the Becquerel named for Henry Becquerel who is credited with the discovery of radioactivity. One Becquerel is equal to one disintegration per second.

It is obvious that the Curie is a very large amount of activity and the Becquerel is a very small amount. To make discussion of common amounts of radioactivity more convenient, we often talk in terms of milli and micro curies or kilo and Mega Becquerels.



Radiation Units

- ◆ Roentgen: A unit for measuring the amount of gamma or X rays in air
- ◆ Rad: A unit for measuring absorbed energy from radiation
- ◆ Rem: A unit for measuring biological damage from radiation

X

Radiation is often measured in one of these three units, depending on what is being measured and why. In international units, these would be Coulombs/kg for roentgen, Grays for rads and Seiverts for rem.

.The majority of the energy received by biologic material from x rays in the diagnostic-energy range is transferred by:X

●

A.

Electrons

○

B.

Degraded gamma photons

○

C.

Protons

○

D.

Spallation products

○ E. 95%

SOME TYPES OF RADIATIONS

10. Cell killing by x rays correlates best with:

○ A. Damage to DNA bases

○ B. The initial number of DNA double-strand breaks

● C. The final number of DNA double-strand breaks

○ D. The number of thymidine dimers

8. The majority of DNA damage due to exposure to x rays is a result of:

○ A. Recoil electrons

○ B. Recoil protons

● C. Hydroxyl radicals

○ D. Hydrated electrons

Key Dates in The History of Radiology

1895 - Rontgen discovers x-rays.

1896 - Becquerel discovers radioactivity.

1901 - Rontgen receives the Nobel Prize in Physics for the discovery of x-rays.

1905 - The first English book on Chest Radiography is published.

1913 -Coolidge introduces the hot cathode tube.

1914 - Von Laue receives the Nobel Prize in Physics for x-ray diffraction from crystals.

1915 - Bragg and Bragg receive the Nobel Prize in Physics for crystal structure derived from x-ray diffraction.

1917 - Barkla receives the Nobel Prize in Physics for characteristic radiation of elements.

1918 - Eastman introduces radiographic film.

1920 - The Society of Radiographers is formed.

1924 - Siegbahn receives the Nobel Prize in Physics for x-ray spectroscopy.

1927 - Compton receives the Nobel Prize in Physics for scattering of x-rays by electrons.

1936 - Debye receives the Nobel Prize in Chemistry for diffraction of x-rays and electrons in gases.

1934 - Joliot and Curie discover artificial radionuclides.

1937 -The first clinical use of artificial radioactivity is done at the University of California- Berkeley.

1946 - Schoenander develops the film cassette changer which allowed a series of cassettes to be exposed at the rate of 1.5 cassettes per second.

1946 - Nuclear medicine is discovered by accident.

1950**'s** - Wide-spread clinical use of nuclear medicine starts.

1950's - Development of the image intensifier and X-ray television.

1956 - The medical use of Ultrasound starts in Poland.

1962 - Kuhl introduces emission reconstruction tomography. This method later becomes known as SPECT and PET.

1967 - The first clinical use of MRI takes place in England.

1972 - CT is invented by British engineer Godfrey Hounsfield of EMI Laboratories in England.

1977 - The first human MRI images are produced.

1979 - Comack and Hounsfield receive the Nobel Prize in Medicine for computed axial tomography.

1980's - The advancement of radiopharmaceuticals and the use of computers transform Nuclear Medicine into what it is today.

1980's - Fuji develops CR technology.

1981 - Siegbahn receives the Nobel Prize in Physics for high resolution electron spectroscopy.

1984 - MRI is cleared for commercial use by the Food and Drug Administration.

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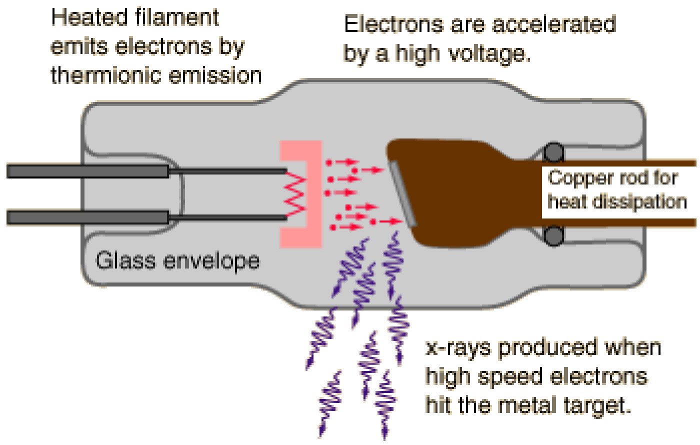
X-ray Tube



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<table><tr><td>Characteristic x-rays</td><td>Brehmsstrahlung</td></tr></table>
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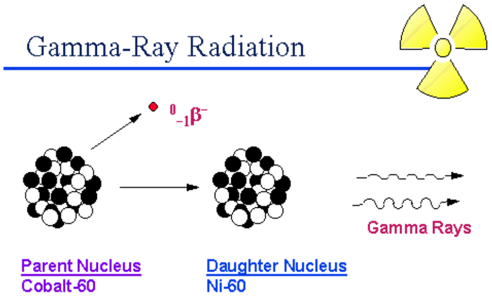
Gamma Radiation



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Like all forms of electromagnetic radiation, the gamma ray has no mass and no charge. Gamma rays interact with material by colliding with the electrons in the shells of atoms. They lose their energy slowly in material, being able to travel significant distances before stopping. Depending on their initial energy, gamma rays can travel from 1 to hundreds of meters in air and can easily go right through people.

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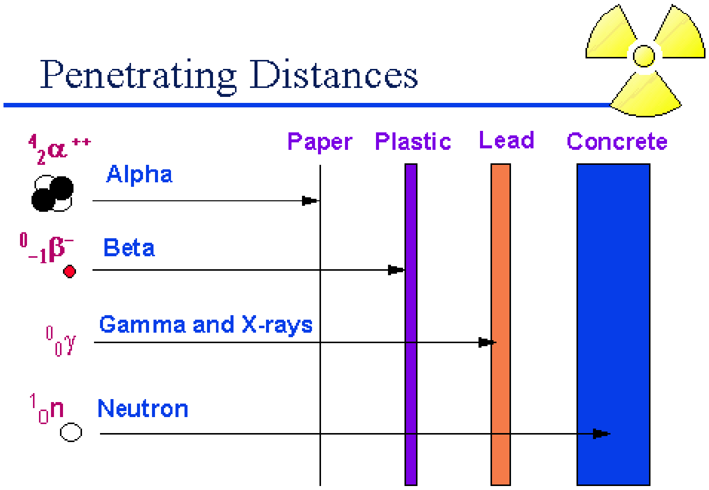

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Beta	Particle	1/1836	±1	Plastic, glass, light metals
Gamma	Electromagnetic Wave	0	0	Dense metal, concrete, Earth
Neutrons	Particle	1	0	Water, concrete, polyethylene, oil

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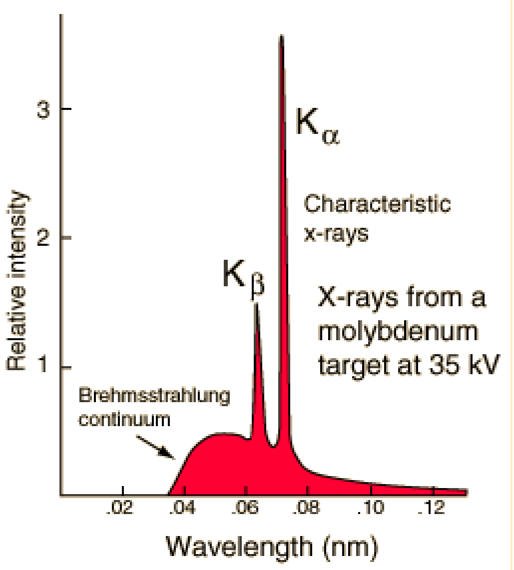
Characteristic X-Rays



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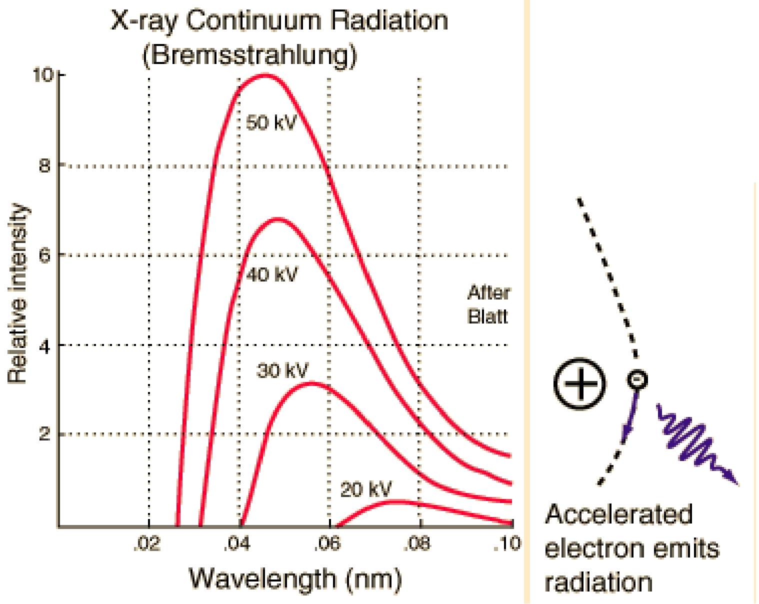
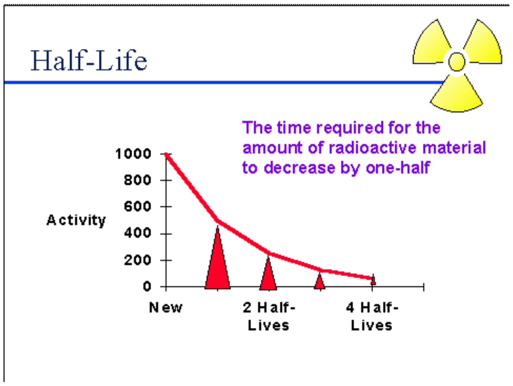
Transitions to the n=2 or L-shell are designated as L x-rays (n=3->2 is L-alpha, n=4->2 is L-beta, etc.). The continuous distribution of x-rays which forms the base for the two sharp peaks at left is called "bremsstrahlung" radiation. X
X-ray production typically involves bombarding a metal target in an x-ray tube with high speed electrons which have been accelerated by tens to hundreds of kilovolts of potential. The bombarding electrons can eject electrons from the inner shells of the atoms of the metal target. Those vacancies will be quickly filled by electrons dropping down from higher levels, emitting x-rays with sharply defined frequencies associated with the difference between the atomic energy levels of the target atoms. X
The frequencies of the characteristic x-rays can be predicted from the Bohr model. Moseley measured the frequencies of the characteristic x-rays from a large fraction of the elements of the periodic table and produces a plot of them which is now called a "Moseley plot". X
Characteristic x-rays are used for the investigation of crystal structure by x-ray diffraction. Crystal lattice dimensions may be determined with the use of Bragg's law in a Bragg spectrometer. X

Bremsstrahlung X-Rays



"Bremsstrahlung" means "braking radiation" and is retained from the original German to describe the radiation which is emitted when electrons are decelerated or "braked" when they are fired at a metal target. Accelerated charges give off electromagnetic radiation, and when the energy of the bombarding electrons is high enough, that radiation is in the x-ray region of the electromagnetic spectrum. It is characterized by a continuous distribution of radiation which becomes more intense and shifts toward higher frequencies when the energy of the bombarding electrons is increased. The curves above are from the 1918 data of Ulrey, who bombarded tungsten targets with electrons of four different energies.X

The bombarding electrons can also eject electrons from the inner shells of the atoms of the metal target, and the quick filling of those vacancies by electrons dropping down from higher levels gives rise to sharply defined characteristic x-rays. X



Half-Life

The time required for the amount of radioactive material to decrease by one-half

Half-life is the time required for the quantity of a radioactive material to be reduced to one-half its original value.

All radionuclides have a particular half-life, some of which a very long, while other are extremely short. For example, uranium-238 has such a long half life, 4.5×10^9 years, that only a small fraction has decayed since the earth was formed. In contrast, carbon-11 has a half-life of only 20 minutes. Since this nuclide has medical applications, it has to be created where it is being used so that enough will be present to conduct medical studies.

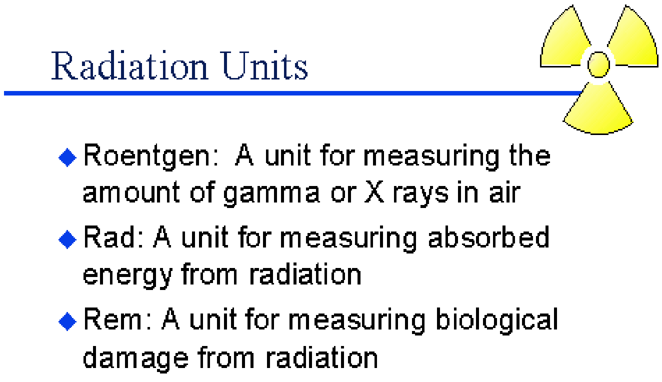
Here is a on-line calculator that will calculate the activity of some radionuclides at some time after it is formed. X

Radiation Measurement

When given a certain amount of radioactive material, it is customary to refer to the quantity based on its activity rather than its mass. The activity is simply the number of disintegrations or transformations the quantity of material undergoes in a given period of time.

The two most common units of activity are the Curie and the Becquerel. The Curie is named after Pierre Curie for his and his wife Marie's discovery of radium. One Curie is equal to 3.7×10^{10} disintegrations per second. A newer unit of activity if the Becquerel named for Henry Becquerel who is credited with the discovery of radioactivity. One Becquerel is equal to one disintegration per second.

It is obvious that the Curie is a very large amount of activity and the Becquerel is a very small amount. To make discussion of common amounts of radioactivity more convenient, we often talk in terms of milli and microCuries or kilo and Mega Becquerels.



Radiation Units

- Roentgen: A unit for measuring the amount of gamma or X rays in air
- Rad: A unit for measuring absorbed energy from radiation
- Rem: A unit for measuring biological damage from radiation

X

Radiation is often measured in one of these three units, depending on what is being measured and why. In international units, these would be Coulombs/kg for roentgen, Grays for rads and Seiverts for rem.

The basis of any method of registration is a quantitative assessment of the processes occurring in the irradiated substance.
The first device to record radiation was Wilson's chamber, which he filled with air or water vapor. If alpha rays of radioactive substance are passed through such a chamber, the alpha particles will knock electrons out of the outer shells of the gas atoms, converting the gas molecules into ions. If you cool the gas in the chamber and reduce the pressure, the vapor will condense and the path of the alpha particles will look like thin strips of fog that can be photographed (Fig. 1.2).

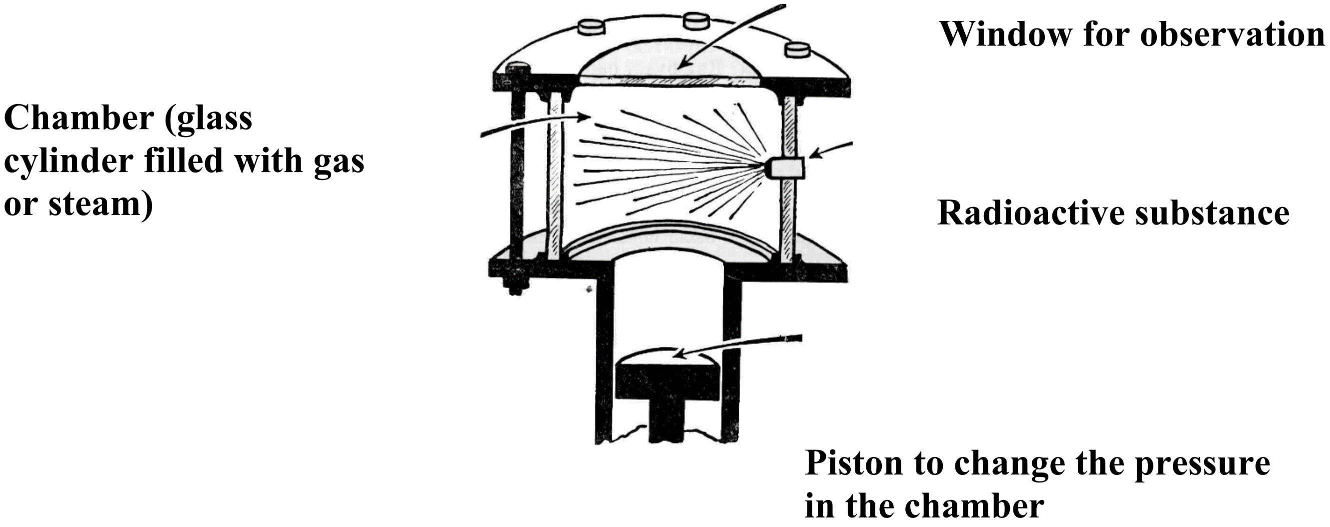


Fig. 1.2. Wilson's camera

In radiation-hygienic practice and medical radi ve become widely used. Depending on the principle of operation, there are ionization, semiconductor (crystal), scintillation, and Cherenkov counters. Due to the peculiarities of semiconductor, scintillation and Cherenkov meters, semiconductor, scintillation and Cherenkov methods of ionizing radiation registration are most often distinguished, respectively.

The principle of operation of the Cherenkov counter is scintillation, but instead of a phosphor a substance is used in which fast electrons are knocked out under the influence of radiation (visible Cherenkov radiation). Let's dwell on each of them separately. The ionization principle of registration underlies the operation of ionization meters. These include proportional counters and counters with independent discharge - Geiger-Mueller counters. These are gas-filled end or cylindrical capacitors-meters, which register each charged particle that got into the meter (Fig. 1.3).

Fig. 1.3. Discharge meters: a) end; b) cylindrical

Semiconductor (crystal) meters are also ionization meters in which a flying particle generates conduction electrons and "holes" in the semiconductor.

Small plates made of cadmium sulfur (CdS), zinc sulfur (ZnS), diamond, silver chloride (AgCl), germanium, silicon and others are included in a special radio circuit. A stream of particles is directed to the plate to be measured. A particle that penetrates a semiconductor generates a large number of current carriers in it: conduction electrons and "holes". The semiconductor inhibits the conductivity, which will instantly affect the growth of electric current. The measuring device is calibrated so that it will show not the strength of the current, but the number of particles that hit the plate. According to the number of registered pulses, a conclusion is made about the number of particles that hit the plate.

Simplicity of the device and operation, the small sizes, high sensitivity, fast growth of a pulse of current are advantage of crystal counters.

Gas discharge meters have an outer cylinder and a thin metal wire stretched along the axis of the cylinder and a wire isolated from it. A voltage of the order of 1000 - 1400 V is applied to the meter. The meter is 90% filled with isopentane alcohol vapors (10%). Pressure - 50-100 mm Hg. The charged particle trapped in the counter forms a large number of ion pairs. Primary ions (electrons) in a strong electric field acquire such energy that they begin to ionize the gas in the meter and create a large number of secondary ions - a gas discharge, which gives a current pulse in the electrical circuit. The number of gas discharges is proportional to the number of particles entering the meter. There is an important indicator of the meter - the resolution - is the number of pulses that can be registered by the meter in 1 sec. It depends on the design and operating voltage. Typically, the meters operate in a mode that is inside the "plateau"

(Geiger zone), when the number of pulses depends only on the number of ionizing particles or gamma quanta hit the detector and depends little on the voltage change (Fig. 1.4).

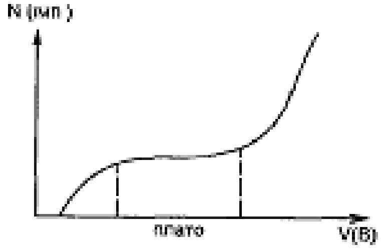


Fig. 1.4. The dependence of the resolution of the Geiger-Mueller counter on voltage.

The scintillation method of registration is based on the registration of light flashes that occur in the scintillator (phosphor) under the action of ionizing radiation (Fig. 1.5.). Many inorganic and organic compounds (CsI (Tl), NaI (Tl), CdS, anthracene, trastilben, naphthalene, tissue-equivalent plastics with the addition of zinc sulfur are used to make phosphors. There are also liquid and gaseous scintillators used to register alpha, -particles, as well as low-energy photon radiation using a photoelectron multiplier (FEP).

There, the scintillations are converted into an electric current, the magnitude and speed of which are proportional to the level of radiation. FEP is a vacuum device that has a photocathode, several dynodes placed in a glass tube at a certain angle to each other and to the anode. The most common photocathode is the antimony-cesium plate. A certain positive voltage is applied to the photocathode K, the dynodes and the anode A, the value of which increases with each voltage on the next pair of dynodes in comparison with the voltage on the previous pair. Under the influence of incident light quanta, electrons break out of the photocathode and are accelerated by the voltage between the photocathode and the first dynode.

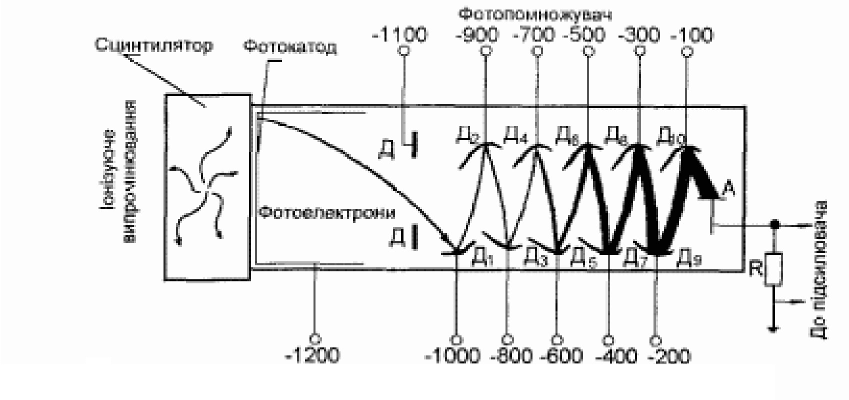


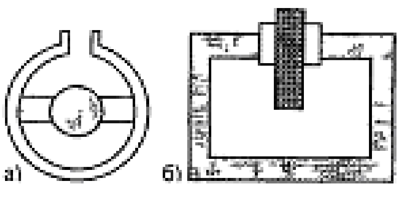
Рис. 1.5. Принципова схема сцинтиляційного лічильника

помножувача. Таким чином, потік електронів від дінода зростає і на останньому електроді (аноді) з'являється у мільйони разів більше електронів, ніж їх вилетіло із фотокатоду. Ці електрони створюють у ланцюгу ФЕП імпульс струму, який потрапляє в лічильний пристрій. У сцинтиляційному лічильнику розміщують сцинтиляційний кристал безпосередньо біля вікна ФЕП. При проходженні іонізуючих частинок крізь кристал виникають сцинтиляції навіть при слабких імпульсах. Люмінофор та ФЕП поміщають у світлонепроникний кожух, і єдине джерело світла — сцинтиляції люмінофора.

The ionization method is based on the measured ionization of the active volume of the detector (ionization chamber) by measuring the electric current or gas discharges occurring in the detector under the influence of ionizing radiation. The simplest ionization chamber is an air-filled flask with two electrodes, which is powered by a DC source. The current is measured with a sensitive galvanometer. Ionization chambers are an integral part of many dosimeters and radiometers used to record the dose, dose rate, particle flux density.

The electrodes can be the walls of the chamber and the rod mounted on the insulator. Ionization chambers are flat, spherical, cylindrical and end. The walls of the chamber are made of air-equivalent materials, ie 1 g of such material must absorb as much energy as 1 g of air. Under normal conditions, the gas between the electrodes is a dielectric and does not conduct electricity. If the charged part passes between the electrodes, the gas is ionized, free electrons and positive ions are created. Under the influence of an electric field, ions move between the electrodes and an ionizing current occurs in the circuit. Its value is proportional to the amount of ionizing radiation entering the ionization chamber.

The voltage value should be such that it includes the possibility of ion recombination (saturation current). The current is measured with a sensitive galvanometer. Ionization chambers are an integral part of many dosimeters used to record doses, dose rates. (Fig. 1.6., 1.7.)



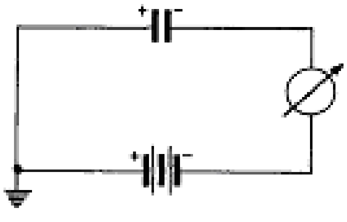


Fig. 1.6. Ionization chamber Fig. 1.7. Electrical diagram of the ionization chamber

Radioluminescent (photoluminescent and thermoluminescent) method

The measurement of ionizing radiation consists in the absorption and accumulation of ionizing radiation energy by special luminescent detectors with its subsequent conversion into luminescent radiation, the intensity of which is proportional to the dose of ionizing radiation and can be registered by thermal stimulation (photoemulation). This property of the phosphor is associated with a shift in the structural lattice of the phosphor crystal.

Thermolumnophores include: LiF, CaF2, Al2O3, Mg2B4O7 and others. As a photoluminophore, for example, aluminophosphate glass is used. Phosphors in the form of powder, tablets, granules, etc. are used to determine the accumulated dose. For example, for individual dosimetry, a thermoluminescent detector (TLD) is inserted into a case and carried with it when in a field of ionizing radiation. After a certain time of dose accumulation, the detector is placed in a measuring device, heated to a certain temperature (200-230C0) and the accumulated dose is determined on the board or scale with an arrow. Detectors are calibrated in advance. Thermoluminescent detectors have a wide energy and dose range.

Such reusable detectors and after appropriate heat treatment are again suitable for measuring doses.

The photochemical method, one of the oldest, is based on the ability of radiation to cause photolysis of silver halide bromide (AgBr). Upon development of the exposed photographic film, silver is reduced to metallic and causes its blackening, the intensity of which is proportional to the absorbed radiation energy, ie dose. This method is used mainly for the registration of individual doses and is quite sensitive, but requires unification of the development of the film and its specific brand.

The chemical method is based on measuring the yield of irreversible radiation-chemical reactions that occur under the influence of ionizing radiation in liquid or solid systems, which change their color due to radiation-chemical reactions. Such reactions include the radiochemical reaction of oxidation of ferrous iron to trivalent. Some organic and inorganic compounds can also change color. The color change is proportional to the energy absorbed in the substance of the detector. The method is used to record significant levels of radiation.

The neutron activation method is associated with the measurement of induced radioactivity. It is used to measure weak neutron fluxes or short-term exposure to large neutron fluxes, and is also used in emergency situations. The activation method is especially widespread in geology, when it is necessary to detect the presence of metal inclusions at a certain depth of drilling by gamma radiation, which is the result of the above activity.

When a person enters the flow of neutrons in his body is the capture of the nuclei of atoms of biological tissue of slow neutrons. The tissue becomes radioactive, which can be determined using gamma counters. Under the action of neutrons, sodium, potassium, phosphorus, chlorine, sulfur, carbon, calcium and other elements contained in the human body are activated. The first three play the greatest role in determining neutron doses because the others have short half-lives.

Biological dosimetry methods are based on the assessment of the reaction that occurs in some tissues when irradiated with a certain dose, such as erythema, the number of chromosomal aberrations, the mortality rate of experimental animals, the degree of leukopenia and others. These methods are not sensitive and accurate enough, so the most common are physical and chemical.

The calorimetric method is based on measuring the amount of heat released in the detector by absorbing the energy of ionizing radiation and is proportional to the energy.

Calculation (mathematical) method used in clinical practice (for example, during radiation therapy and other cases).

Types and means of protection against ionizing radiation

There are four methods (factors) of protection against ionizing radiation:

1. **Time protection**. The shorter the contact time with the source of ionizing radiation, the lower the radiation dose.
2. **Distance protection.** The farther from the source of ionizing radiation, the lower the dose received. The dependence is inversely quadratic, because the rays from the source go radially and are distributed over a sphere whose area is πR2. Thus, the flux density will decrease in proportion to the square of the distance. Use remote control devices.
3. **Screen protection.** They are made of dense high-atomic materials (brick, concrete, barite concrete). If compact protection is required, lead or high-atom uranium (in ɣ-therapeutic devices) is used. Sometimes simpler materials are used. For example, glasses for protection against β-rays are made of organic glass, not leaded glass, because β-particles will be inhibited and form R-rays that will penetrate deeper.That is, different screens are used for different types of radiation. Alpha rays can trap a thin barrier, such as a sheet of paper; high-energy beta rays cannot pass through a human palm, and they can also be trapped by an aluminum plate several mm thick; gamma rays are able to penetrate deep into the substance or pass through thick barriers. Neutrons are better absorbed by low-atom screens - water, paraffin.

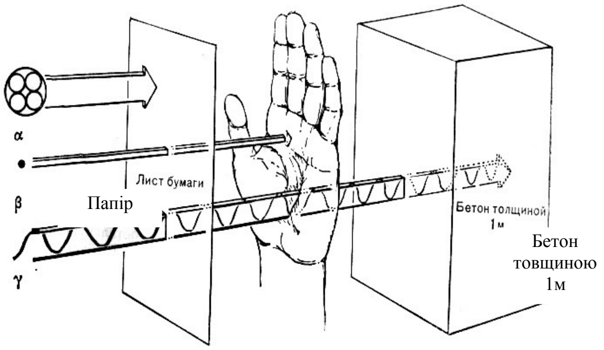


Fig. 1.1. Penetrating ability of different types of ionizing radiation

4. **Quantity protection.** The lower the power of the source or the number of RFP staff, the lower the radiation dose. Be sure to protect the patient from radiation that he does not need (the less we use a radioactive drug for diagnosis, the better for staff and others). The X-ray machine uses an electron-optical amplifier. In order for the image to be bright enough at a lower flux of rays, and the dose per patient and doctor to be lower, a current of 0.3-0.4 mA is applied to the X-ray tube instead of 3-4 mA, and this is enough to obtain a high-quality image. This is especially important during preventive medical examinations.

Means of protection are:

1. Collective (walls, ventilation, screens).
2. Individual (goggles, face shield, gloves, lead rubber apron, plastic boot covers, mask, spacesuit).

Regulatory documents. Population groups

Conditions and permissible levels of exposure of the population are determined by the Norms of Radiation Safety of Ukraine (NRBU-97). There are 4 groups of radiation and hygiene regulations (Table 1.3).

Table. 1.3. Groups of radiation and hygienic regulations

Group of regulations	Purpose of installation	Terms of use	The main regulated values
The first	Restriction of occupational exposure	Normal operation of industrial sources	1. Dose limits 2. Derivative levels 3. Permissible levels 4. Control levels
The seccond	Restrictions on medical exposure	Medical practice	Recommended limit levels
Third	Intervention of emergency radiation doses	Radiation and radiation-nuclear accidents	1. Levels of intervention 2. Levels of action
Fourth	Intervention of radiation doses from technogenic enhanced sources	Man-made strengthening of natural sources	1. Levels of intervention 2. Levels of action

Radiation hygienic regulations of the first group

Dose limits are regulations that aim to limit exposure.

Acceptable levels are the levels of doses or radioactive substances that may be present in the workplace, on the premises of the work area and outside them. Irradiation of personnel of category A and category B is regulated, admissible doses for all population - category B. Here additional restriction of irradiation of pregnant women and women of childbearing age and children is specified. During pregnancy, it is not desirable to conduct radiological examinations (only for vital signs).

Table. 1.4. Irradiation dose limits (mSv / year)

	Category of persons exposed to radiation		
	А а) б)	Б а)	В а)
DLE (effective dose limits)	20 в)	2	1
External radiation equivalent dose limits:			
- DLlens (for the lens of the eye)	150	15	15
-DLskin (for skin)	500	50	50
-DLextrim (for bones and feet)	50	50	-

Notes:

a) - radiation doses for the year are regulated;

b) - for women of childbearing age (up to 45 years) and pregnant women, the dose does not exceed 2mSv for two consecutive months;

c) - on average for any consecutive 5 years, but not more than 50 mSv for a single year (DLmax).

6. Materials for self-control of quality of preparation.

A. Questions for self-control

1. Name the recommended limits of medical exposure

Category AD. Patients undergoing research on cancer, precancerous diseases, in order to diagnose cardiovascular disease, urgent patients.

The maximum allowable dose (MPD) is 150 mSv / year.

Database category. Patients who are being examined for somatic non-oncological diseases, to establish a diagnosis that will shape the tactics of further treatment.

GDD - 15 mSv / year.

Category VD. Cancer patients who are examined after radical treatment, periodic examinations of prescribed categories of the population for prevention. All other persons - preventive examinations, volunteers, examinations in medical programs for scientific purposes

GDD - 1 mSv / year.

2.What are Radiation Control Levels?

Control levels are hygienically introduced levels to control the radiation dose. If this year we work at the maximum dose, so that next year we do not exceed it, despite the fact that there is a certain limit, we must use doses less limited. This applies to everyone: staff, patients, others. At local irradiation dose limits are bigger. Until 1997, the permissible total radiation dose for Group A personnel was 50 mSv / year, and from January 1, 1998, lower doses were taken (Table 1.4).

3.How are safe conditions of contact with sources of ionizing radiation regulated?
In order to regulate safe conditions of contact with sources of ionizing radiation, the following categories of persons are distinguished:
Category A (specialists) - persons who work directly with sources of ionizing radiation.
Category B (staff) - specialists whose workplaces are located near the sources of ionizing radiation (for example, a therapist whose office is next to the X-ray room).
Category B - the entire population.

4. What are the Permissible Levels of Radiation Doses?
Acceptable levels are the levels of doses or radioactive substances that may be present in the workplace, on the premises of the work area and outside them. Irradiation of personnel of category A and category B is regulated, admissible doses for all population - category B. Here additional restriction of irradiation of pregnant women and women of childbearing age and children is specified. During pregnancy, it is not desirable to conduct radiological examinations (only for vital signs).

1. What remedies do you know?

Means of protection are:

1. Collective (walls, ventilation, screens).
2. Individual (goggles, face shield, gloves, lead rubber apron, plastic boot covers, mask, spacesuit).

2. What types and means of protection against ionizing radiation exist?

There are four methods (factors) of protection against ionizing radiation:

1. Time protection.
2. **Distance protection.**
3. **Screen protection.**
4. **Quantity protection.**

3. What methods of ionization radiation registration do you know?

1.The ionization method
2.Radioluminescent (photoluminescent and thermoluminescent) method
3.The photochemical method
4.The chemical method
5.The neutron activation method
6.Biological dosimetry
7.The calorimetric method
8. Calculation (mathematical) method

B. Tests for self-control with standards of answers.

1. Which of the following is correct in order of lowest to highest frequency?

   None ○ [A] X-rays, Visible Light, Microwave
   ○ [B] Ultraviolet, Visible Light, Gamma-rays
   ● [C] Microwave, Visible Light, Gamma-rays

2. This type of emission maps the dust between stars.

   None ○ [A] Infrared ★
   ● [B] Ultraviolet
   ○ [C] X-rays
   ○ [D] Gamma-rays

3. Gas in space emits radio waves.

   None ○ [A] True ★
   ● [B] False
   ○ [C] We don't know

4. This type of emission can come from radioactive materials.

   None ○ [A] Radio
   ○ [B] X-rays
   ● [C] Gamma-rays

6.The percentage of x-ray damage to biological material mediated by free radicals is closest to:

○ A. 5%

○ B. 33%

○ C. 50%

● D. 67%

7. Which of the following is an SI unit?

○ A. Rad

○ B. Rem

● C. Sievert

○ D. Curie

8. The majority of DNA damage due to exposure to x rays is a result of:

○ A. Recoil electrons

○ B. Recoil protons

● C. Hydroxyl radicals

○ D. Hydrated electrons

7. The information necessary for the formation of knowledge and skills can be found in textbooks:

1. Essential radiology for medical students, interns and residents // A.Ahuja. – OMF publishing. – 2017. – 518 p.
2. Kovalsky O. Radiology. Radiotherapy. Diagnostic Imaging: textbook for students of higher med. education establishments of IVth accreditation level / O. Kovalsky, D. Mechev, V. Danylevych. — 2nd ed. — Vinnytsia: Nova Knyha, 2017. — 504 p
3. Diagnostic Radiology: textbook for medical students, residents, doctors, researches / M.I. Pilipenko, Y.E. Vikman, M.E. Slabodchikov [et al.]. - Kharkiv, 2018. - 260 p.

8. Materials for classroom independent training:

6.1. The list of educational practical tasks that must be performed during the practical (laboratory) lesson:

1. Know the basics of nuclear physics (types of ionizing radiation, units, dosimetry).
2. Solve problems in nuclear physics.
3. Correctly choose the methods and techniques of protection against the main types of ionizing radiation.
4. Use the main types of radiometers and dosimeters.
5. Justify the use of a dosimeter or radiometer in different conditions.
6. Master the basic physical units used in radiation diagnostics and therapy.

9. The topic of the next lesson. « Final control of mastering the discipline».

10. Tasks for UDRS and NDRS on the topic of the next lesson.

Methods of X-ray examination (basic (General) and special (auxiliary). The concept of radioscopy and radiography. Structure and principle of operation of equipment for X-ray examinations. Characteristics of the radiation used in these studies. Methods of X-ray examination: radiography, radioscopy, planar tomography, fluorography. Advantages and disadvantages of each method. Principles of image acquisition in X-ray examination methods (radiation source and detector); purpose of methods – study of morphology or (and) function; contraindications to performance; projections and sections of the study. Fundamentals of X-ray skialogy. Natural and artificial contrast. Contrasting substances. Indications for their use. Construction of clinical and radiological diagnosis. Coronary heart disease. Hagiography of cerebral vessels.

Methodical recommendations made by __________ as. Kaouk AS