Radioactivity and Measurement

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- There are four different but interrelated units for measuring radioactivity, exposure, absorbed dose, and dose equivalent. These can be remembered as
- **R-E-A-D**

- Radioactivity refers to the amount of ionizing radiation released by a material.
- Whether it emits alpha or beta particles, gamma rays, x-rays, or neutrons, a quantity of radioactive material is expressed in terms of its radioactivity (or simply its activity), which represents how many atoms in the material decay in a given time period.
- The units of measure for radioactivity are the curie (Ci) and becquerel (Bq).

- Radioactivity is measured by the rate of decay- disintegrations per unit time.

- The international unit of disintegration is the Becquerel, Bq, which is equal to 1 disintegration per second.

- In nuclear medicine, the amount of radioactive material administered to the patient is expressed in Curie rather than in grams.
- Typical doses of diagnostic procedures range from a few μCi s up to 10-20 mCi, depending on the isotope used.

- The Curie is a very large unit.
- One Curie source represents a considerable hazard.
- 1 Curie source with a long half life should be treated carefully.
- It is equivalent to the activity of 1 gram of Radium.

- Most experimental work involves microCurie or milliCurie samples.

- 1 mCi = 3.7×10^7 Bq

- 1 μCi = 3.7×10^4 Bq

Activity Units:

- Curie is the unit used for stating activity- rate of emmission of the source of radioactivity.
- The Becquerel is the new unit for source of activity in the SI unit system.

- Energy and type of radiation strongly affect its ionizing power.
- **E**xposure units describe the amount of ionizations when radiation traveling through the air.
- Many radiation monitors measure exposure.
- The units for exposure are the roentgen (R) and coulomb/kilogram (C/kg).

- The formal definition of one Roentgen is
- the radiation intensity required to produce an ionization charge of 2.58×10^{-4} Coulombs per kg of air.
- !!Note: Charge here refers to charge of electrons liberated by ionization:

- charge of an electron = - 1.6 x 10^{-19} Coulomb
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- 1 Roentgen = 2.08×10^{9} ion pairs / cm^3
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- $d_{air} = 1.293 \times 10^{-6}$ kg / cm^3
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- 2.08×10^{9} / $1.293 \times 10^{-6} = 1.6 \times 10^{15}$; $(1.6 \times 10^{15}) \times (1.6 \times 10^{-19}) = 2.58 \times 10^{-4}$ C / kg

- Radiation measuring instruments usually are calibrated in Roentgens.
- The output of X-ray machines is specified in Roentgens or sometimes mR.
- The Roentgen applies only to X-rays and γ-rays and their interactions with air.

- It is based on the amount of ionization radiation produced in air, which is not closely related to TISSUE DAMAGE.
- The term EXPOSURE corresponds to the quantity that expresses the ionization produced by X- or γ-rays interacting in a volume

Absorbed Dose

- **A**bsorbed dose describes the amount of radiation absorbed by an object or person (that is, the amount of energy that radioactive sources deposit in materials through which they pass).
- The units for absorbed dose are the radiation absorbed dose (rad) and gray (Gy).

- The RAD or Gray measure the radiation energy absorbed in the target material.
- The basic quantity that characterizes the amount of energy imported to the matter is the Absorbed Dose.

- The rad or Gray are the unit of radiation dose.
- Biological effects usually are related to the absorbed dose, and therefore the rad is the unit most often used when describing the radiation quantity received by a patient
- It expresses the absorbed radiation dose in terms of the energy actually deposited in the tissue.

- The rad is defined as an absorbed dose of 0.01 Joule of energy per kg of tissue.
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- 1 rad = 0.01 Joules / kg

- The Gray is the new SI unit for absorbed dose and is defined as 1 joule of absorbed energy per kg of tissue.
- Therefore 1 Gy = 100 rads = 1 J/kg

Biological effectiveness

- **D**ose equivalent (or effective dose) combines the amount of radiation absorbed and the medical effects of that type of radiation.
- For beta and gamma radiation, the dose equivalent is the same as the absorbed dose.
- By contrast, the dose equivalent is larger than the absorbed dose for alpha and neutron radiation, because these types of radiation are more damaging to the human body.
- Units for dose equivalent are the roentgen equivalent man (REM) and sievert (Sv), and biological dose equivalents are commonly measured in 1/1000th of a REM (known as a millirem or mREM).

- The REM is a unit designed to measure the radiation dose in terms of its biological effectiveness in MAN and the unit name is "rad-equivalent man".

- It is used to express the quantity of radiation received by radiation workers
- 1 Sievert = 100 REM
- The dose in REMs is defined as the dose in rads multiplied by a "quality factor" which is an assessment of the biological effectiveness of that particular type and energy radiation. It is related to LET.

- QF: The factor expressing the relative effectiveness of a given particle based on its linear energy transfer.
- Value of QF as a function of LET are assigned primarily on the basis of animal experiments.

	QF
X or γ	1
β	1
Neutrons	10
Protons	10
α	20

Quantity	Customary unit Name (Symbol)	SI unit
Exposure	Roentgen (R)	Coulomb /kg
Absorbed dose	rad (rad)	Gray (Gy)
Dose eqiuvalent	rem (rem)	Sievert (Sv)
Radioactivity	Curie (ci)	Becquerel (Bq)

- Most X-rays used in diagnostic radiology have energy up to 150 keV (an electron that is accelerated by an electrical potential of one volt will acquire energy to one eV (1 eV = $1.6x19^{-19}$ J), whereas those in radiotherapy are measured in MeV.
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- Other radiologically important energies such as electron and nuclear binding energies and mass energy equivalence, are also expressed in eV.
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- Because diagnostic radiology is concerned primarily with X-rays, for our purposes we may consider 1 R = 1 rad = 1 rem.
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- The Roentgen has persisted in dosimetry, but it is not applicable to α, β and other particle radiation and does not accurately predict the tissue effects of γ-rays of extremely high energies.
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