X-ray Production 10047/10046 Cheat Sheet

by miami (miami.faris) via cheatography.com/132065/cs/26665/

Types of Radiation

Particulate	Electromagnetic
Alpha	X-ray
Beta	Gamma
Neutrons	

Particulate Radiation

All radiation particles have two features in common: they all have a mass and they are all subatomic particles. Since particles have a mass (and sometimes a charge) = HIGH interaction between radiation and matter. This is one of the reasons particulate radiation is not used for medical imaging; **low pentating ability** (we need radiation to pass through the patient and still interact with the patient, but particulate radiation have very high **Linerar Energy Transfer**

Alpha Paticles

> released by nuclei of unstable atoms (uranium-238, plutonium-236).
> consist of 2 protons and 2 neutrons (net positive charge: +2 --> identical to helium atom).
> high **L.E.T**; because of their heavy weight and high charger.
> can be stopped by a piece of paper

Beta Particles

> two types: electrons and positrons. Both orginate from an unstsbale atom and have high energy and speed
> Beta+ decay: when excess protons --> proton converts into. Position and neutrino produced.

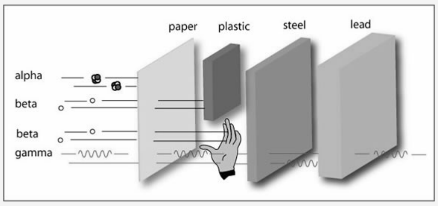
Particulate Radiation (cont)

> Beta- decay: when excess neutrons --> neturon converts into proton. Electron and antineutrino produced (rearely used in medical imaging)
> Positrion has low atomic mass, (+1 charge). Low mass and charge = lower LET, higher penetrability compared to alpha particles.
> stopped by a few milimetres of aluminium

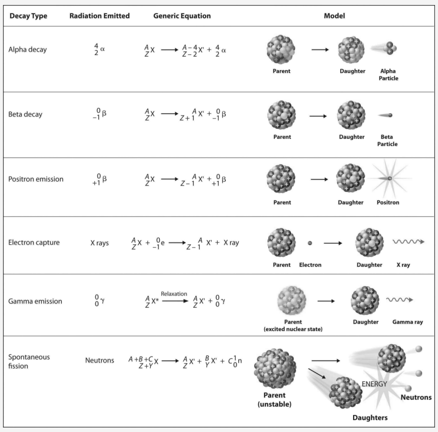
Neutrons

> bypoduct of nuclear fission or fusion.
> similar mass to proton, but no charge

Radiation Penetrating Power

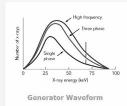


Particulate vs Electromagnetic Radiation



Decay Type	Radiation Emitted	Generic Equation	Model
Alpha decay	${}^{4}_{2}\alpha$	${}^{A}_{Z}X \longrightarrow {}^{A-4}_{Z-2}X' + {}^{4}_{2}\alpha$	Parent → Daughter Alpha Particle
Beta decay	${}^{0}_{-1}\beta$	${}^{A}_{Z}X \longrightarrow {}_{Z+1}{}^{A}X' + {}^{0}_{-1}\beta$	Parent → Daughter Beta Particle
Positron emission	${}^{0}_{+1}\beta$	${}^{A}_{Z}X \longrightarrow {}_{Z-1}{}^{A}X' + {}^{0}_{+1}\beta$	Parent → Daughter Positron
Electron capture	X rays	${}^{A}_{Z}X + {}^{0}_{-1}e \longrightarrow {}_{Z-1}{}^{A}X' + \text{X ray}$	Parent Electron → Daughter X ray
Gamma emission	${}^{0}_{0}\gamma$	${}^{A}_{Z}X^{*} \xrightarrow{\text{Relaxation}} {}^{A}_{Z}X' + {}^{0}_{0}\gamma$	Parent (excited nuclear state) → Daughter Gamma ray
Spontaneous fission	Neutrons	${}^{A+B+C}_{Z+Y}X \longrightarrow {}^{A}_{Z}X' + {}^{B}_{Y}X' + C{}^{1}_{0}n$	Parent (unstable) → Daughters ENERGY Neutrons

Generator type and Emission Spectrum



Change in Generator: note that as the efficiency of the generator increases, so does the x-ray quantity given the same amounf of electricity used. This goes back to X-ray circuitry: reduced ripple effect, consistent levels of kVp with high-free-quency generator.

Electromagnetic Radiaiton

They are chargless and mass-less; "-packets of energy"
* they can travel in straightlines through empty space/vacuum.
* they are transmitted by electric and magentic fields oscilating at right angles to each other
* travel at the speed of light (in a vacuum).
* they are unaffected by external magnetic/-electric fields
* wave-particle duality. for medical imaging, we view X-rays and Gamma rays more as a wave.
* low wavenlengths, high frequencies; higher frequences = higher energy

X-ray Production

* Created from the interarctions of high-speed (high KE) electrons with target (e.g. tungsten).

two types: *charactersitic and bremssthr-alung radiation*

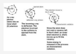
Charactersitic Radiation

Characteristic radiation involves the fillament electrons interacting with orbital electron of target atom. Created when orbital electrons are removed from their shell and outer-shell elelctrons fill inner--shell vacancies (usually K-Shell electrons that are ejected). To fill vacancy: potential energy is releaserd as a characteristic photon. AKA. since the binding energies differ between orbiting shells: outer-shell electrons (low BE) fills inner-shell vacancy (high BE). Energy released is the difference between the inner-shell BE and outer-shell BE.. For characteristic radiation to even occur, the incident electron (fillament electron) MUST have a HIGHER than the relevant BE.
resultant characteristic x-rays are specific to certian shell-shell transitions and USUALLY do not provide sufficient energy to even leave the target atom, never mind the patient

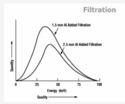
Binding Energies for Tungsten

K Shell	69.5 keV
L Shell	12.1 keV
M Shell	2.82 keV
N Shell	0.6 keV
O Shell	0.08 keV
P Shell	0.008 keV

Charactersitic Radiation

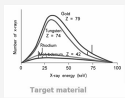


Filtration and Emission Spectrum



Added filtration: increases in tube filtration causes a decrease in X-ray beam quantity and an increase in quality, but the energy of characteristic x-rays are unaffected.

Target Material and Emission Spectrum



Change in Target Material: note that as the atomic number of the material increases, so does the average energy and qunatity of the x-rays and the position of the discrete line (characteristic x-rays) changes. Greater atomic numbers represent 'bigger' targets for the fillament electrons to interact with. This increases the likelihood of interactions and the number of photons produced. The characteristic x-rays are different as they are atom specific.

Bremssthrahlung Radiation

Brems photons are produced when filament electrons miss all of the orbital electrons of the target atoms and interact with the nucleus. The attraction of the fillament electron to the nucleus causes it slow down and change direction. the resultant loss of energy is given off as a brems photon.

Bremssthrahlung Radiation (cont)

Unlike characteristic x-rays where very specific energies are produced, brems photons have a much larger range of energy levels. *The amount of directional change imposed on the incident electron dictates the amount of energy released*

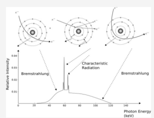
Important conclusions about X-ray production:

1) Knowing that the average energy of brems is 1/3 of the kVp selected and that most of the beam is made up of brems: we can predict average energy of an x-ray beam to be 1/3 of the kVp selected

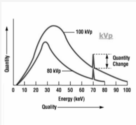
2) A number of X-rays are at very low energies (& have no diagnostic value). This highlights need for filtration. Inherent filtration from X-ray tube housing (glass envelope, oil) removes ~50% of X-rays generated at the anode. The added filtration of aluminium removes 80% of THE REMAINDER. this means that there is leakage radiation.

3) X-ray production is not efficient: Most interactions (99%) do not result in X-rays, but produce only heat. only 1% of interactions result in X-ray production either by characteristic or brems interactions. Basically, when incident electrons hit the target, 99% only result in excitation of the target atom's electrons and 1% results in ionisation.

Brems vs. Characteristic

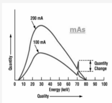


kVp and Emission Spectrum



Change in kVp: purple curve (increased kVp), increases the quantity and quality of brems x-rays. It does not change the position of the charactersitic radiation line = does not change the energy of characteristic x-rays, just the quantity of them.

mAs and Emission Spectrum



Change in mAs/ma: increasing mAs or mA will increase the quantity of radiation (because increased current supply to the fillament = more incident electrons hitting the target anode). Increasing mAs/mA has no affect on the quality (average energy) of X-rays and the energy of the characteristic x-rays

Factors Affecting Emission Spectrum

Increase in	Effect on Quantity	Effect on Quality
mA/mAs	increases	no effect
kVp	increases	increases
Tube Filtration	decreases	increases
Generator type	increases	increases
Target Material (atomic number)	increases	increases