

Ministry of Higher Education and Scientific Research

Al-Mustaqbal University College

Radiology Techniques Department



Radiation Physics

Al-Mustaqbal University College

2<sup>nd</sup>

Radiology Techniques Department

By

Assistant lecturer

**Prof.Dr.Raad Shaker Alnayli**

**MS.c.Reem Taumu Yousif**

**Lecture5 :Factors Affecting X-ray Emissin Spectrum**

**(Quality and Quantity of X-Ray)**

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## X-Ray Quantity

**X-ray quantity** is the number of x-ray photons in the useful beam.

The intensity is a measure of quantity of radiation. The term exposure is often used in radiology

## X-Ray Quality

The term **quality** describes the penetrating power of the radiation.

**The penetrability** of an x-ray beam is called the x-ray quality. X-rays with high penetrability are termed high-quality x-rays

❖ High-energy x-rays are able to penetrate tissue more deeply than low-energy x-rays.

X-rays with high penetrability are termed high-quality x-rays

## Factors That Affect X-ray Quantity and Quality

A number of factors under the control of radiographers influence the size and shape of the x-ray emission spectrum and therefore the quality and quantity of the x-ray beam

## Exposure Time

Exposure time determines the length of time over which the x-ray tube produces x-rays.

- An increase or decrease in mA, exposure time, or mAs directly affects the quantity of x-rays produced;
- Patient dose is directly proportional to exposure time.
- **Automatic Exposure Control (AEC):** These devices terminate the exposure when a specific quantity of radiation has reached the IR

## Effect of mA and mAs (Tube Current and Time)

The product of tube current in milliamperes and exposure time in seconds (mA \* sec) describes the total number of electrons bombarding the target.

### Calculating mAs

$$\text{mAs} = \text{mA} \times \text{seconds}$$

Examples:

$$200 \text{ mA} \times 0.25 \text{ s} = 50 \text{ mAs}$$

$$500 \text{ mA} \times 2/5 \text{ s} = 200 \text{ mAs}$$

**Example:** Calculate the total number of electrons bombarding the target of an x-ray tube operated at 200 mA for 0.1 sec

- The ampere, the unit of electrical current, equals 1 coulomb/sec.
- The product of current and time equals the total charge in coulombs.
- X-ray tube current is measured in milliamperes, where 1 mA =  $10^{-3}$  amp.
- The charge of the electron is  $1.6 \times 10^{-19}$  coulombs, so

$$1 \text{ mA} \cdot s = \frac{(10^{-3} \text{ coulomb/sec})(\text{sec})}{1.6 \times 10^{-19} \text{ coulomb/electron}}$$

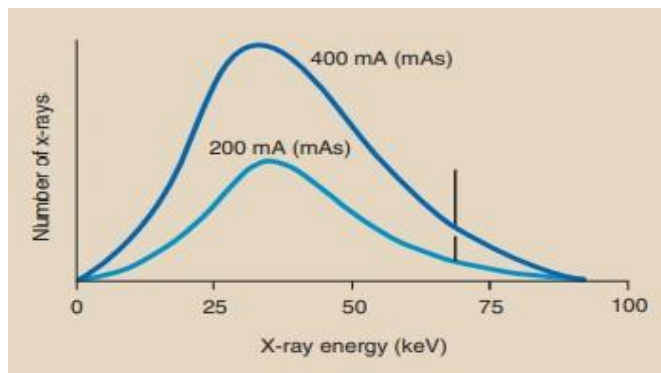
Remember that mAs is just a measure of the total number of electrons that travel from cathode to anode to produce x-rays.

$$\begin{aligned} \text{mAs} &= \text{mA} \times s \\ &= \text{mC/s} \times s \\ &= \text{mC} \end{aligned}$$

where C (coulomb) is a measure of electrostatic charges and 1 C =  $6.25 \times 10^{18}$  electrons.

$$\begin{aligned} &= 6.25 \times 10^{18} \text{ electrons} \\ \text{No. of electron} &= (200 \text{ mA})(0.1 \text{ sec})(6.25 \times 10^{18} \text{ electrons/mA}\cdot\text{sec}) \\ &= 1.25 \times 10^{16} \text{ electrons} \end{aligned}$$

A change in mA or mAs results in a proportional change in the amplitude of the x-ray emission spectrum at all energies.



X-ray quantity is directly proportional to the mAs

$$\frac{I_1}{I_2} = \frac{\text{mAs}_1}{\text{mAs}_2}$$

where  $I_1$  and  $I_2$  are the x-ray intensities at  $\text{mAs}_1$  and  $\text{mAs}_2$ , respectively

**Example2:** The radiographic technique for a kidneys, ureters, and bladder (KUB) examination uses 74 kVp/60 mAs. The result is a patient exposure of  $2.5 \text{ mGy}_a$ . What will be the exposure if the mAs can be reduced to 45 mAs?

$$\frac{I_1}{2.5 \text{ mGy}_a} = \frac{45}{60}$$

$$I_1 = \frac{2.5mGy_a \times 45}{60} = 1.9mGy_a$$

The tube current affects only the quantity or the amount of x-ray photons produced but not the quality of the X-rays.

**i.e. the intensity is  $\propto$  mA.**

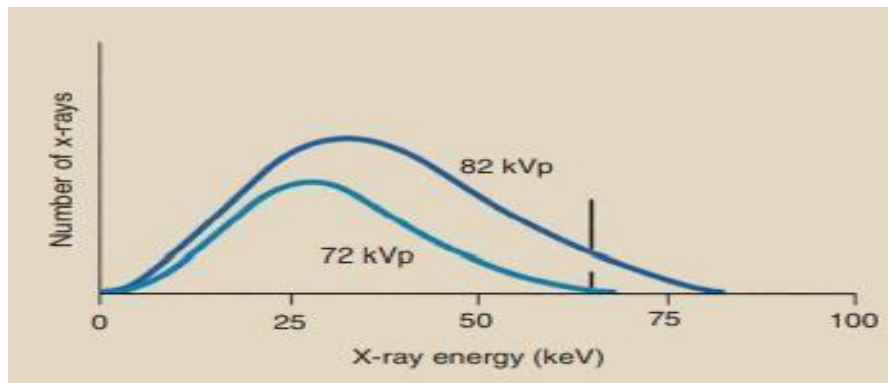
Milliamperage (mA) is a measure of the current flow rate in the x-ray tube circuit. It determines the number of electrons available to cross the tube and thus the rate at which x-rays are produced

### Effect of Kilovolt Peak (kVp) (Tube Voltage)

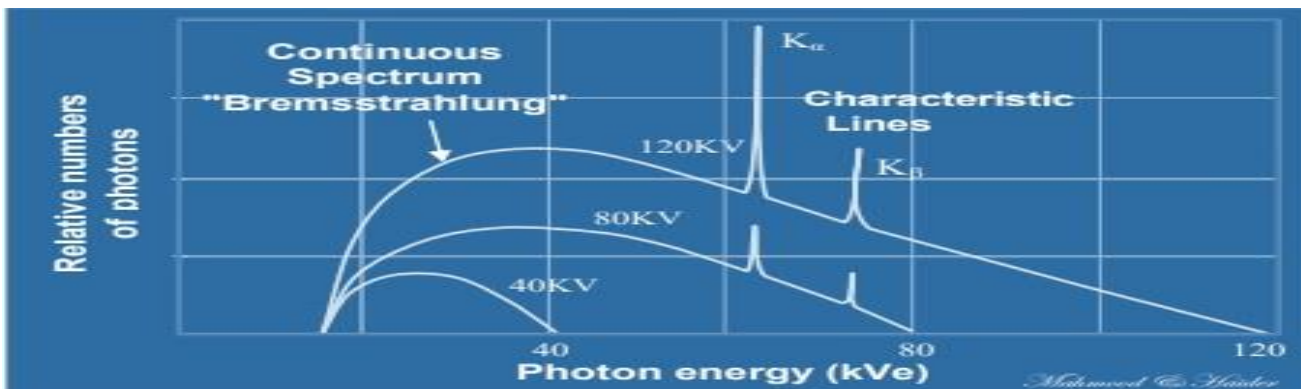
When kVp is increased:

- The maximum photon energy
- the X-ray production efficiency
- The intensity
- Quality of the X-rays

A change in kVp affects both the amplitude and the position of the x-ray emission spectrum.



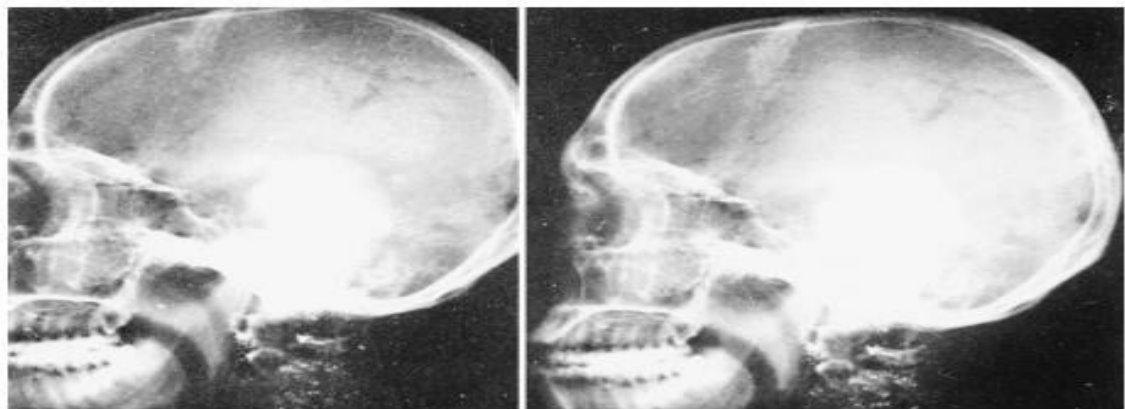
A change in kVp has no effect on the position of the discrete x-ray emission spectrum



**The rule states that a 15% increase in kVp is equivalent to doubling the mAs.**

- ❖ A 15% increase in kVp does not double the x-ray intensity but is equivalent to doubling the mAs to the image receptor.
- ❖ To double the output intensity by increasing kVp, one would have to raise the kVp by as much as 40%.
- ❖ Radiographically, only a 15% increase in kVp is necessary because with increased kVp, the penetrability of the x-ray beam is increased.
- ❖ Therefore, less radiation is absorbed by the patient, leaving a proportionately greater number of x-rays to expose the image receptor

**i.e. Radiation exposure (E)  $\propto$  (kVp)**



70 kVp / 120 mAs  
665 mR

80 kVp / 60 mAs  
545 mR



90 kVp / 30 mAs  
230 mR

In other words, if we double it, the x-ray intensity would increase by a factor of four.

$$\frac{I_1}{I_2} = \left(\frac{KVp_1}{KVp_2}\right)^2$$

Where  $I_1$  and  $I_2$  are the X-ray intensities at  $KVp_1$  and  $KVp_2$ , respectively

**Example:** A lateral chest technique calls for 110 kVp, 10 mAs and results in an x-ray intensity of 0.32 mGy<sub>a</sub>. What will be the intensity if the kVp is increased to 125 kVp and the mAs remains fixed?

$$\frac{0.32mGy_a}{I_2} = \left(\frac{110}{125}\right)^2$$

$$I_2 = (0.32mGy_a) \left(\frac{110}{125}\right)^2$$

$$I_2 = (0.32mGy_a)(1.14)^2$$

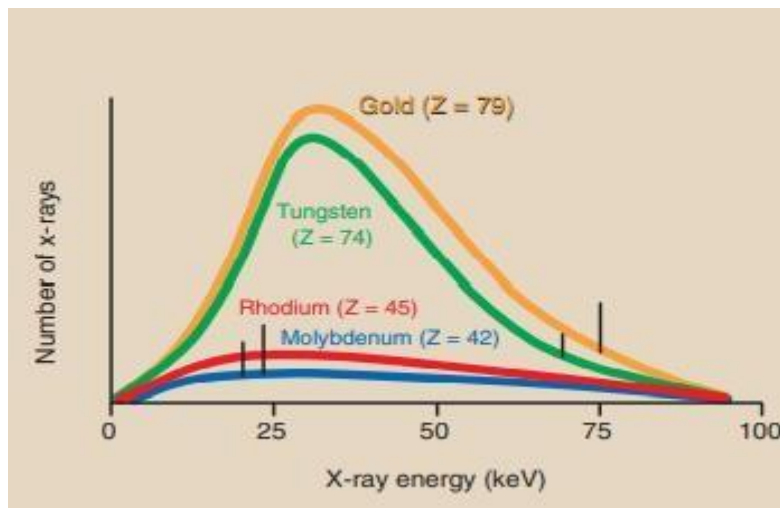
$$I_2 = (0.32mGy_a)(1.29) = 0.41mGy_a$$

### Effect of Target Material

The atomic number of the target affects both the number (quantity) and the effective energy (quality) of x-rays.

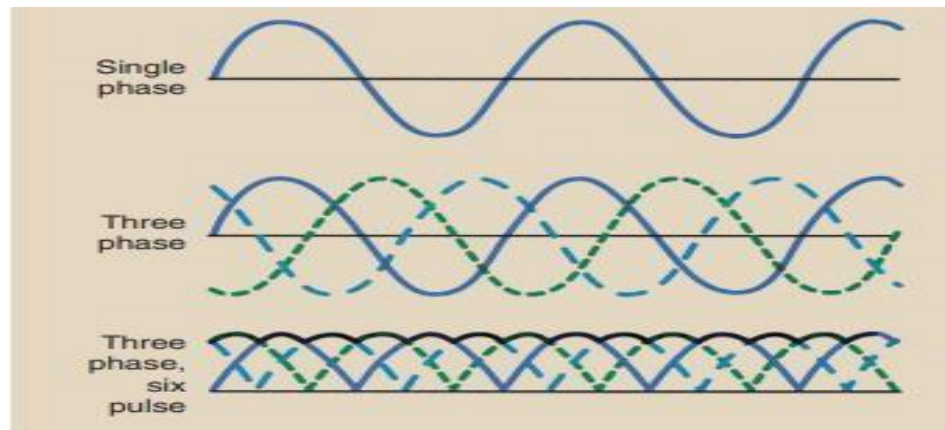
As the atomic number of the target material increases:

- Increase characteristic energy
- enhances the efficiency of x-ray production
- Increase energy of bremsstrahlung x-rays.



## Effect of Voltage Waveform

- There are five voltage waveforms: half-wave-rectified, full-wave-rectified, three-phase/six-pulse, three-phase/ 12-pulse, and high-frequency waveforms
- The x-rays produced when the single-phase voltage waveform has a value near zero are of little diagnostic value because of their low energy; such x-rays have low penetrability.
- With three-phase power, the voltage applied across the x-ray tube is nearly constant, never dropping to zero during exposure.



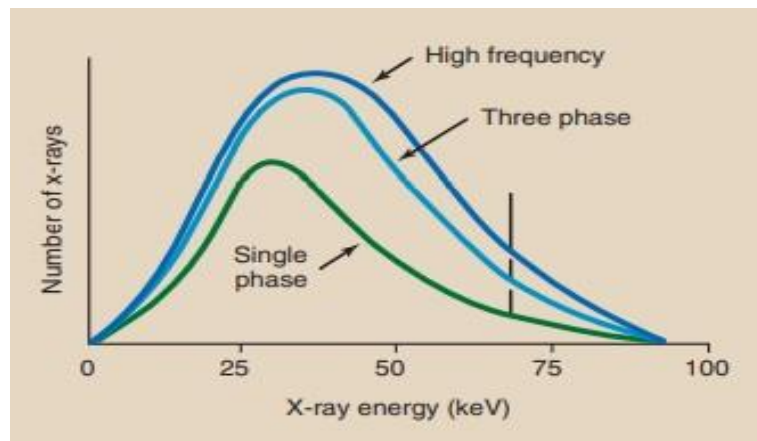
- High-frequency generators produce a nearly constant potential voltage waveform, improving image quality at lower patient radiation dose.



Where an x-ray emission spectrum from a full-wave-rectified unit, all operated at 92 kVp and at the same mAs:

- The x-ray emission spectrum that results from high-frequency operation is more efficient than that produced with a single-phase or a three phase generator
- Increased quantity of x-ray photons
- Increased average energy
- Minimum and maximum energy is constant





## Effect of Added Filtration

- Filters are thin sheet of material (Al,Cu).
- The purpose of using filter is to reduce patient exposure at the skin level.
- Filters alter both the quality and quantity of X-rays by selectively removing the low energy photons in the spectrum.
- This reduces the photon number (quantity) and shifts the average energy to higher values by increasing the quality.

