



# Fundamentals of Radio-physics

First Semester

**Week11-12: Factors Affecting X-ray Emission Spectrum  
(Quality and Quantity of X-Ray)**

By

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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**

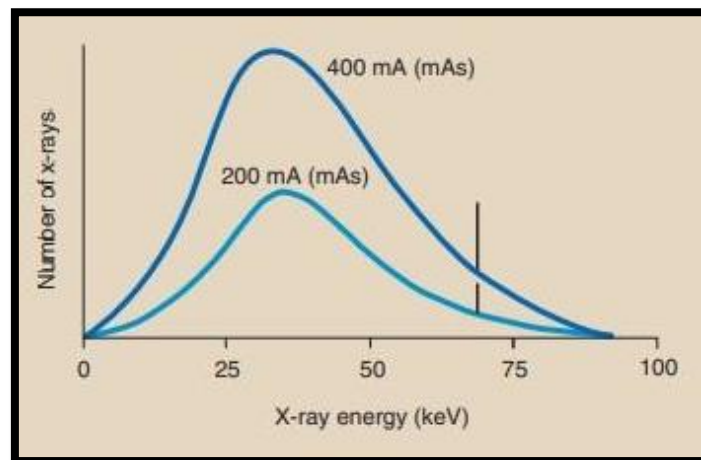
$$\text{mAs} = \text{mA} \times \text{seconds}$$

Examples:

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

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

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

$$\frac{I_1}{I_2} = \frac{mAs_1}{mAs_2}$$

where I1 and I2 are the x-ray intensities at mAs1 and mAs2, 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 mGya. What will be the exposure if the mAs can be reduced to 45 mAs?

$$\frac{I_1}{2.5\text{mGya}} = \frac{45}{60}$$

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

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 a mA.**

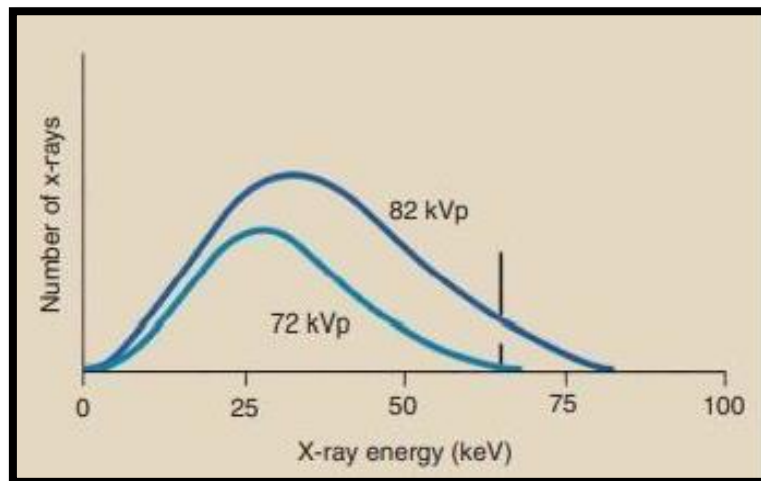
**Milliamperage (mA)** is a measure of the current flow rate in the x-ray tube circuit. It determines the number of electrons available to cross the tube and thus the rate at which x-rays are produced.

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

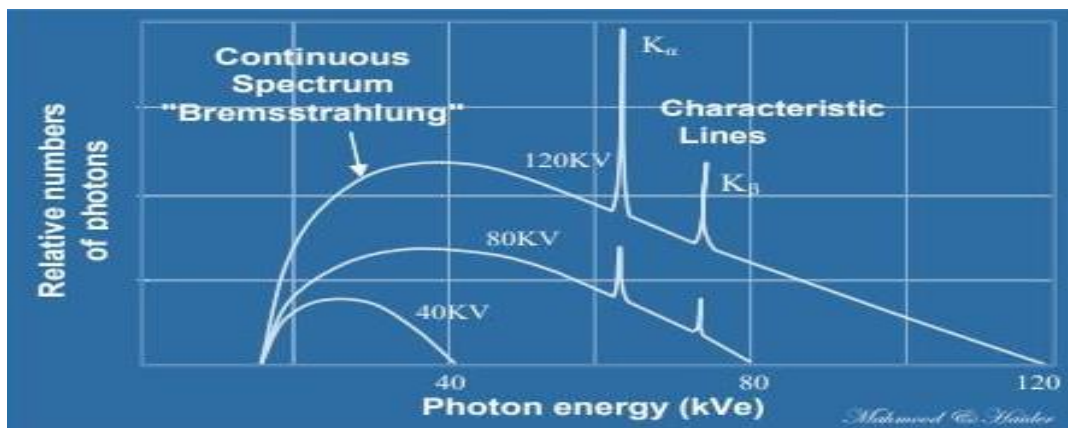
When kVp is increased:

- ☐ 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

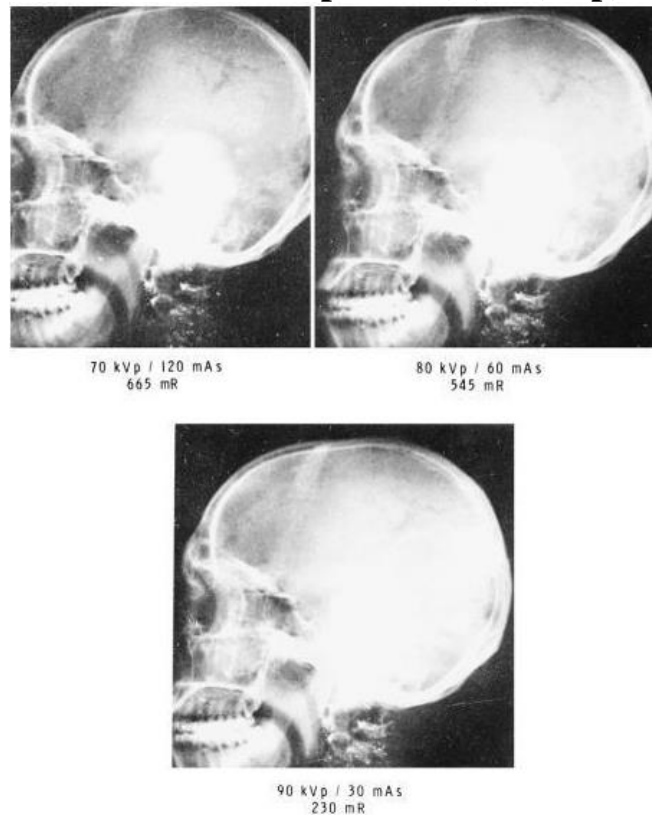


**The rule states that a 15% increase in kVp is equivalent to doubling the mAs.**

- ❖ 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)**



**In other words, if we doubled, 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 mGya. What will be the intensity if the kVp is increased to 125 KVp and the mAs remains fixed?

$$\frac{I_1}{I_2} = \left(\frac{kvp_1}{kvp_2}\right)^2$$

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

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

$$I_2 = (0.32\text{mGya})(1.14)^2$$

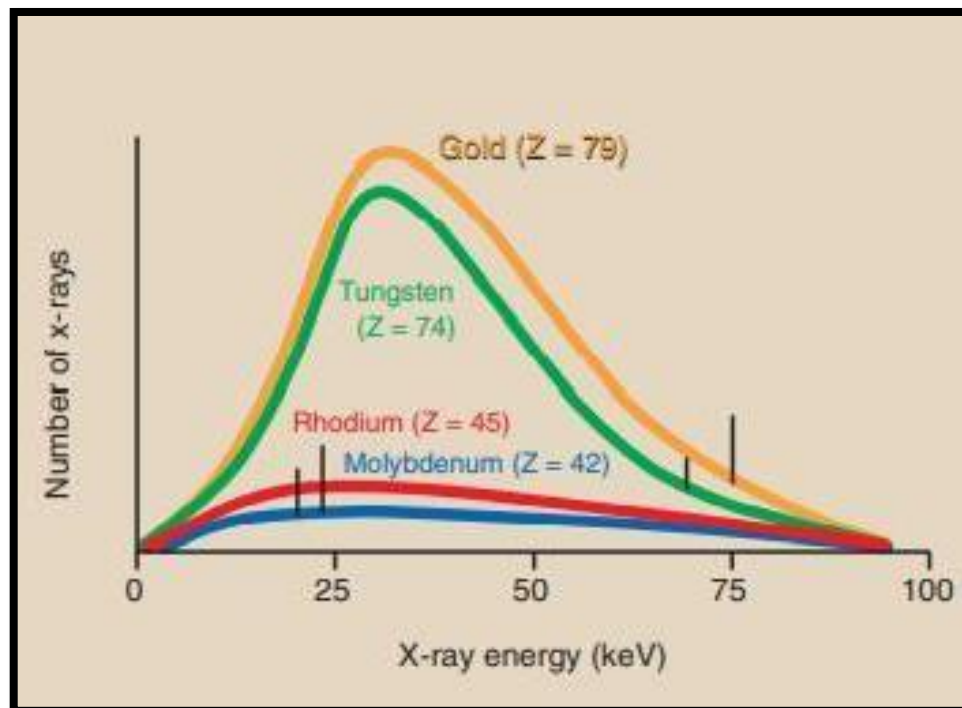
$$I_2 = (0.32\text{mGya})(1.29) = 0.41\text{mGya}$$

### ➤ Effect of Target Material

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

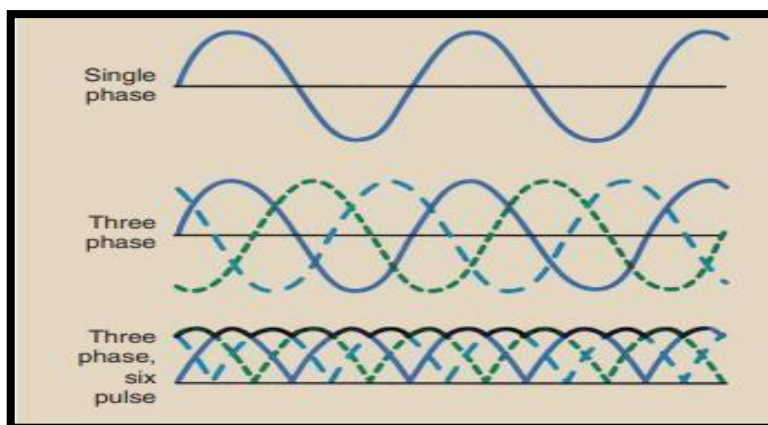
**As the atomic number of the target material increases:**

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



### ➤ Effect of Voltage Waveform

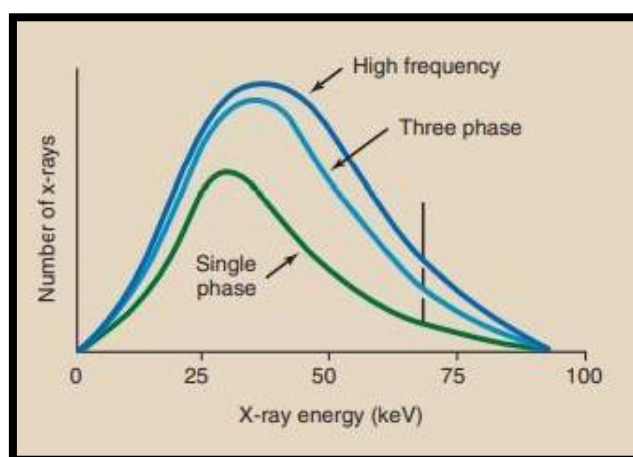
- ☐ There are five voltage waveforms: half-wave-rectified, full-wave-rectified, three-phase/six-pulse, three-phase/ 12-pulse, and high-frequency waveforms
- ☐ The x-rays produced when the single-phase voltage waveform has a value near zero are of little diagnostic value because of their low energy; such 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:**

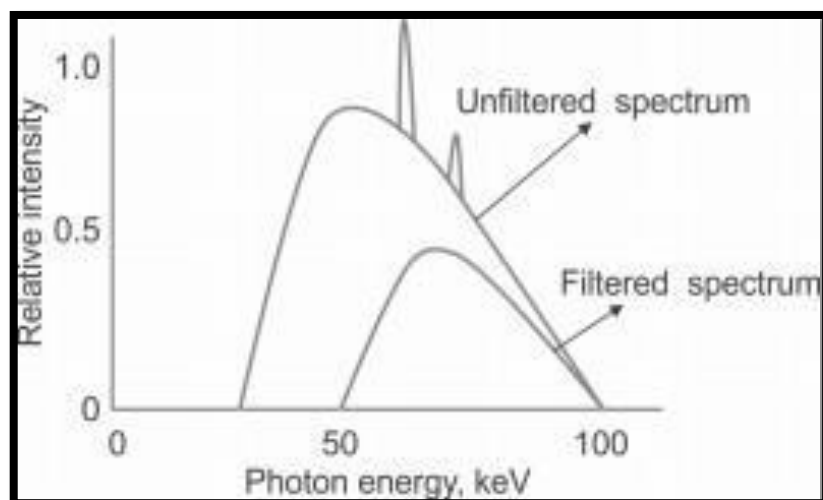
- ☐ The x-ray emission spectrum that results from high-frequency operation is more efficient than that produced with a single-phase or a three phase generator
- ☐ Increased quantity of x-ray photons
- ☐ Increased average energy
- ☐ Minimum and maximum energy is constant



### ➤ **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





An Increase in	Results in
Current (mAs)	An increase in quantity; no change in quality
Voltage (kVp)	An increase in quantity and quality
Added filtration	A decrease in quantity and an increase in quality
Target atomic number (Z)	An increase in quantity and quality
Voltage ripple	A decrease in quantity and quality