APPH 226: **Emission Spectrum**

Objectives:

1.5 Explain how components of the x-ray tube may affect the beam

of the beam

MRT Program

- Define **Polyenergetic**: many energies

- The x-ray beam is polyenergetic and consists of a wide range of energies known as the x-ray emission spectrum
- X-ray beam consists of:
  - Bremsstrahlung
  - Characteristic

Spectrum

- Why do we need one in x-ray?
  - At a glance, can see what was emitted most and least often
  - With a spectrum of x-ray energy emissions, we can describe what is emitted from the x-ray tube
  - As factors are modified, we can see what the effect is on the energy of the x-rays emitted
    - E.g. techniques – mAs, kVp

Emission Spectrum

- Simply put, it is a graph of the number of x-ray photons and the range of energies the photons possess at a given exposure setting
  - _____ Spectrum
    - Contains only specific values
  - _____ Spectrum
    - Contains all possible values

Emission Spectrum

- Affected by changing several parameters
  - kVp
  - mAs
  - Target material
  - Filtration
  - Voltage Waveform

kVp vs. keV

- keV = kilo electron volt
  - Measurement used for:
    - Binding energies
    - Energy of incident electron
- When the technologist sets the kVp, they are setting the forces with which incident electrons interact with the tungsten target

kVp vs. keV

- The projectile/incident electrons accelerated from cathode to anode do not all have the peak kinetic energy
- kVp is the **peak energy** being sent across the tube
  - E.g. if 80 kVp is set, it means the maximum energy crossing the tube is 80 keV

kVp vs. keV

- Although some electrons are at the highest energy, majority are around 30-40% of the peak energy
- Many of the low energy incident electrons end up creating heat
  - In fact… 99% cause heat

kVp vs keV

- E.g. If the kVp set was 80 kVp
  - What is the maximum energy?
    -
  - What would the average energy be?
    -

Bremsstrahlung Emission Spectrum

- If we could measure the energy contained in each Bremsstrahlung x-ray emitted from the tube, we would find the energy range to be from 0 to whatever the kVp was set at

Bremmstrahlung Emission Spectrum

- How do we calculate the energy of Brems emitted radiation?
  - Subtract the incoming vs the outgoing energy of the incident electron
  - Maximum incoming it could be is the **kVp set**
  - Provides a range of energies from 0 to the max kVp set

Bremmstrahlung Emission Spectrum

- Maximum energy = kVp set
  - Not very many
- Average energy is about 30-40% of the maximum energy
  - Majority of the x-ray are in this range
- Minimum energy is 0

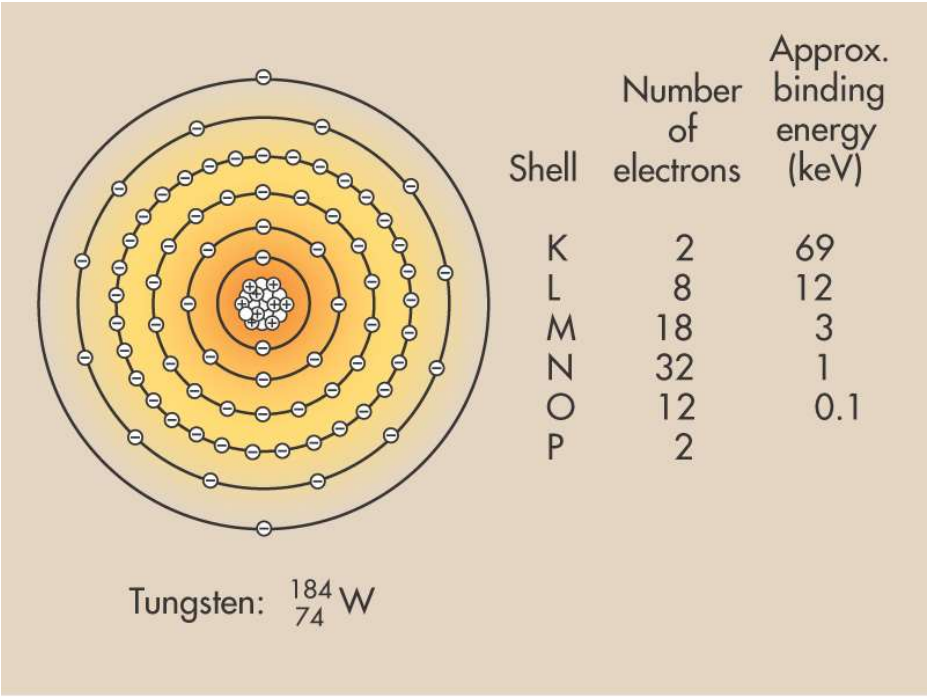
- Creates a **heterogenous** or **polyenergetic** x-ray

Characteristic Emission Spectrum

- Only occurs between certain energies, usually above 70 kVp
- Why?
  - An incident electron travelling below 70 keV cannot knock an electron out of the K shell of a tungsten atom.
    - K-shell of tungsten – binding energy of 69.5 keV
- How would we calculate the energy of each emitted photon?
  - Find the difference between the binding energies of the electron ejected minus the one that took its place

Tungsten

- The binding energies are characteristic of the element which is Tungsten in this case.
- K shell differences in binding energies are:
  - K-L = 57 keV
  - K-M = 66 keV
  - K-N = 68 keV
  - K-O = 69.4 keV
  - K-P = 69.5 keV



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Characteristic Emission Spectrum

- There are many other energies, but the ones from the K shell are the only ones strong enough to make it out of the x-ray tube
- Between all the shells, there are 15 possible energies produced – 5 of which are useful for x-ray

Characteristic Emission Spectrum

- Because there are so few photon energies that can be created with characteristic

  radiation and because they are

  so close together, they are most often

  represented by a spike or line at 69 keV

X-Ray Emission Spectrum

- The general shape of an x-ray spectrum is always the same, but its relative position can change
- The larger the area under the curve, the higher the x-ray **intensity** or **quantity**

mA - Quantity

- mA- the number of electrons available to move from cathode to anode
- As we increase our mA, we **increase** the number of electrons boiled off at the filament
- Increasing mA, proportionally increases the # of photons at all energy levels
  - Therefore, increasing the **amplitude** of the spectrum

mA

- If we manually changed the technique from 200 mA to 400 mA
- We would send a stronger current to the filament
- Boil off 2X the amount of incident electrons
- And create 2X the amount of x-rays

mAs

- What is mAs?
  - # of electrons that are sent in 1 second.
- The number of x-rays reaching the target is also determined by the time we set
- When we set the time we use seconds
    - Some machines will have fractions on them instead of times
- Exposure time determines how long the electrons will pass from cathode to anode.
- Like mA, exposure time is **directly** proportional to the number of electrons crossing the tube
  - therefore directly proportional to the number of x-rays created.

mAs

- When we set the **quantity** of radiation we are setting the mAs
- 200 mA x 0.5 seconds = 100 mAs
  - If this combination gave us 10,000 x-rays
- 200 mA x 0.25 seconds = 50 mAs
  - This combination would give us 5000 x-rays

mA, time and mAs all affect **quantity** of x-rays
All are directly proportional

kVp

- The kVp will affect the **quality** and the **quantity** of the x-rays

kVp

- As we increase the kVp we are increasing the **force** with which the incident electrons hit the anode
- As the kVp increases the curve moves to the right
- Why?
  - Because the maximum energy increases
  - The average energy is 30-40% of that
  - The average energy increases

kVp

- This means that the average x-ray energy is higher as the kVp is increased.
- This improves the _____ of the x-ray
  - Quality refers to the strength of radiation
- A stronger x-ray photon is better able to penetrate our patients.

kVp

- As well as moving to the right the spectrum will grow in amplitude (height)
- Why?
  - Because when the incident electrons hit the anode at a greater speed they create more x-rays – a lot more

kVp

- As the kVp increases
  - We increase the **quantity** of the photons created
  - There are **more** photons that will reach the image receptor
- Because kVp will increase the number as well as the quality of the x-rays
  - A technologist only has to increase the kVp by _____% to double the amount of photons hitting the receptor

    -not directly proportional

Target Material

- As we increase the atomic number of the target material, the efficiency of the CHARACTERISTIC RADIATION _____
- Why?
  - Because the binding energy for each shell increases

Target Material

- For example the K shell electron in a tungsten atom (Z=74)is bound more tightly than the K shell of Molybdenum (Z=42)
- Therefore the difference in binding energies will create different strength and number of x-rays

Target Material

- Notice the location of the characteristic radiation spike
  - Will be characteristic to the binding energies of the target material
  - Will happen at whatever energy level required to knock out the k-shell binding energy

Target Material

- As the atomic number increases so does the **efficiency** with which the target produces brems xrays
  - Most positive pull with more protons in nucleus
  - Able to lose more energy in the form of x-rays

More x-rays increases the quantity of x-rays produced
and therefore the amplitude of our spectrum will increase

Draw an Emission Spectrum at 90 kVp



Readings

- Bushong: Radiologic Science for Technologists 11th Ed.
  - Pg 127-132 (Skip "Effect of added filtration" and stop before "Effect of Voltage Waveform")