PAM1014
Introduction to Radiation Physics

"X-Ray Production"

In This Lecture

- X-rays
  - Brief History
  - Production
  - X-ray Tube
  - Spectrum

History

- X-rays and radioactivity were discovered by accident
- Wilhelm Roentgen (1895)

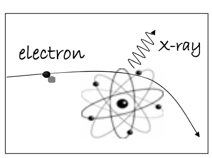
History

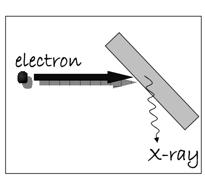
http://imagers.gsfc.nasa.gov/ems/xrays.html

X-ray Production

<u>Overview</u>

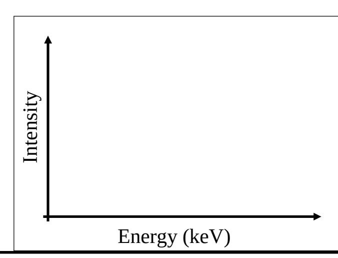
- Electrons accelerated towards target
- Deceleration of electrons in striking a target
- Energy released as high frequency electromagnetic radiation





X-ray Spectrum

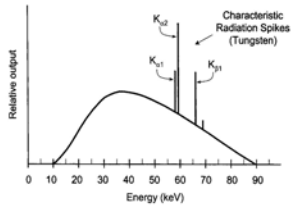
- X-rays are characterised by there energy
  - Quoted in keV
- A spectrum is a graph plotting intensity vs energy



X-ray Production

- Two x-ray production process occur

1. Brehmsstrahlung radiation
2. Characteristic x-rays



X-ray Production

<u>Bremsstrahlung Radiation</u>

- Does an electron lose all its energy in just one single collision?

OR

- Is an electron involved in impacts with many atoms, producing a large amount of low energy photons?
- Bremsstrahlung "Breaking radiation"

Bremsstrahlung radiation

- Bremsstrahlung is characterized by:
  - Continuous distribution of radiation
  - Referred to as 'the continuous x-ray spectrum'
- More intense and shifting towards higher frequencies when the energy of the bombarding electrons is increased.

Bremsstrahlung radiation

- An electron can lose any amount of its kinetic energy in an interaction with the target atom
- Bremsstrahlung radiation associated with the loss can take on a corresponding range of values.

Bremsstrahlung radiation

- An electron with kinetic energy of 70 keV can lose:
  - All
  - None
  - Any intermediate level

  of its kinetic energy in a Bremsstrahlung interaction

Bremsstrahlung radiation

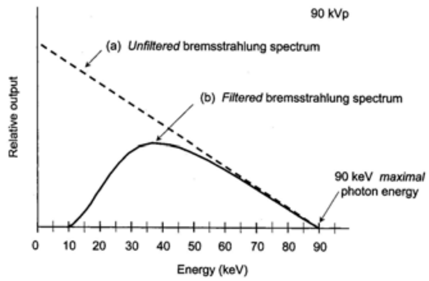
- Bremsstrahlung emission can have an energy in the range of 0 to 70 keV.
- 70 keV corresponds to the cut off wavelength

$$E(eV)= hc/\lambda$$
$$\lambda_{min} = hc/eV_{max}$$

- Different from the production of characteristic x-rays that have discrete energies.

Bremsstrahlung spectrum

Energy distribution for a 90 kVp acceleration potential



Production of X-rays

<u>Characteristic X-ray Lines</u>

- The bombardment of targets of heavy atoms by fast moving electrons causing energy levels in the target to change.
- The energy released from K shell transition by electrons returning to the ground state!

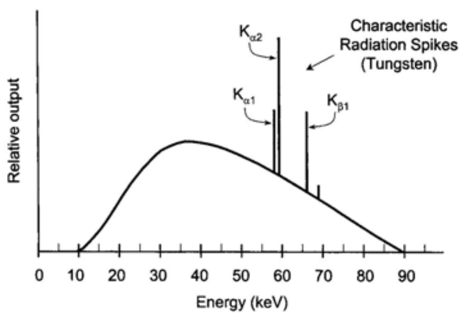
Characteristic x-rays

- Produced by transitions of orbital electrons from outer to inner shells.
- Bombarding electrons can release electrons from inner energy level orbits.
  - Higher electrons then fall into the vacancy.
  - If the energy gap between the levels is sufficient X-ray will be produced.

Characteristic x-rays

- Electron binding energy for every element is different
  - Unique characteristic X-rays.
- ‘Characteristic’ because it has precisely fixed, or discrete, energies.
- Effective energy characteristic X-rays increases with increasing atomic number of the target element.

Characteristic x-rays

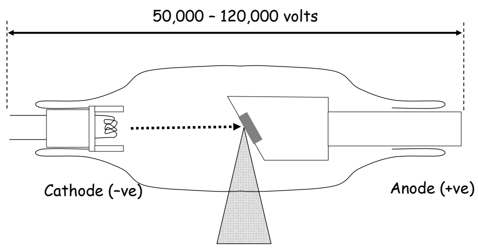


X-Ray Tube

- How do we accelerate these electrons?
- Electric Field
- Energy in keV
- Energy in Joules = e x Voltage

X-ray Tube (insert)

- Evacuated Glass tube



X-ray tube

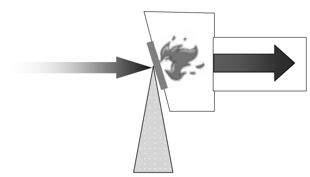
- Source of Electrons
- Filament
- Electrons are produced by thermionic emission in the cathode.
- Heated by a relatively low current supply.

X-ray tube

- For example:
  - At a cathode current of 100 mA
  - 6 x 10^{17} electrons travel from the cathode to the anode of the X-ray tube every second.
  - They are accelerated from the cathode to anode across a high voltage.

Thermal Energy

- Less than 1% of the electron energy is converted into photons.
- 99% is ?



Thermal Energy

- The electrons interact with the outer-shell electrons of the target atoms but do not transfer sufficient energy to these outer-shell electrons to ionize them.
- Outer-shell electrons are simply raised to an excited, or higher, energy level.

Thermal Energy

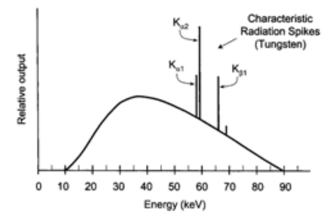
- The outer-shell electrons drop back to their normal energy state emitting infrared radiation.
- Constant excitation and re-stabilization of outer-shell electrons is responsible for the heat generated in the anodes of X-ray tubes.

Target Material

- High Z (proton number) so that transitions of high enough energy to emit X-ray radiation are possible
- High melting point because so much heat energy is produced.
- Tungsten is ideal for standard diagnostic tubes
- Molybdenum is ideal for mamography tubes

Effect of Tube Current

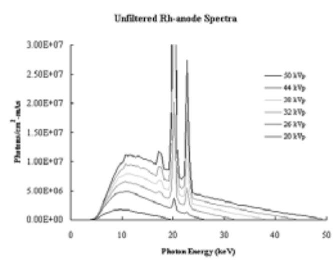
- What is the tube current?
- No difference in shape



- Different area under curve
  More electrons = more photons

Effect of tube Voltage

- Increase tube voltage
- Increase kinetic energy of electrons
- Increase maximum x-ray photon energy



Summary

- X-rays
  - Brief History
  - Production
  - X-ray Tube
  - Spectrum