X-Ray

Basic Principle and Applications

Dr. R. Prasad
Department of Zoology,
Eastern Karbi Anglong College, Sarihajan

Radiation

Radiation: Radiation is the energy that travels through space or matter.

Ionizing and Non-ionising Radiation

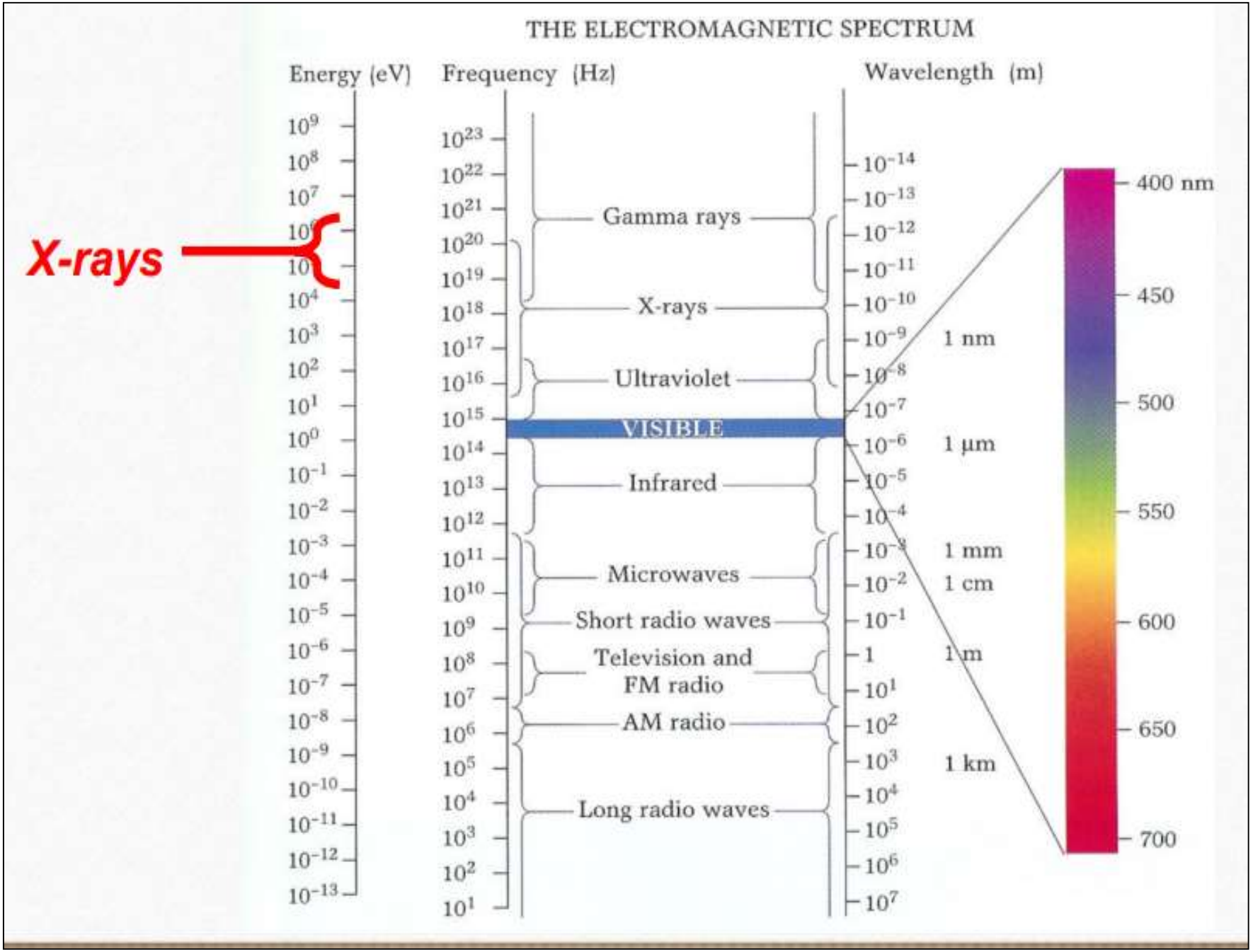
- The radiation that we are exposed to can be ionizing or non-ionizing, depending on whether or not the radiation has enough energy to remove an electron from an atom with which it interacts.
- **Ionizing radiation:** is the type of radiation which causes the formation of ions (electrically- charged atoms or molecules) when interacting with matter. These ions can lead to biological damage in cells.
- X-rays, gamma rays, neutrons, cosmic rays are ionizing radiation. They contain enough energy per photon to eject electrons from the atoms with which they interact.
- **Non-ionising radiation:** is the type of radiation which does not have enough energy to eject electrons from the atoms with which they interact, hence can not cause ionisation
- Visible light, infrared waves, radiofrequency waves are non-ionizing radiation.

Electromagnetic Radiation: Electromagnetic radiation (EM) has no mass, is unaffected by either electrical or magnetic fields and has a constant speed in a given medium.

- Although EM radiation propagates through matter, it does not require matter for its propagation. Its maximum speed occurs $3X10^8$ m/sec in vacuum.

EM radiations used in diagnostic imaging include:

- **X-rays**, which are produce outside the nucleus and are used for radiological imaging purposes (radiography, mammography, computed tomography, Dental equipment etc.)
- **Gamma rays**, which are emitted from the nuclei of radioactive atoms (used to image the dtribution of radiopharmaceuticals in Nuclear Medicine as diagnostic procedure).


THE ELECTROMAGNETIC SPECTRUM
Energy (eV)
Frequency (Hz)
Wavelength (m)
X-rays
Gamma rays
X-rays
Ultraviolet
VISIBLE
Infrared
Microwaves
Short radio waves
Television and FM radio
AM radio
Long radio waves
1 nm
1 μm
1 mm
1 cm
1 m
1 km
400 nm
450
500
550
600
650
700

X-Rays and Gamma Rays

- X-rays and gamma rays are differed only **by their origin in the nucleus**.
- **Gamma rays** originate within the nucleus of the atom, whereas **X-rays** are generated outside the nucleus by the interaction of high speed electrons with the atom.
- Gamma rays emitted by a single radionuclide consist one or several discrete energies.
- X-rays consist of a broad spectrum of energies.
- X-rays and gamma rays are alike in their mode of interaction with matter, their biological effects and their photographic effects.

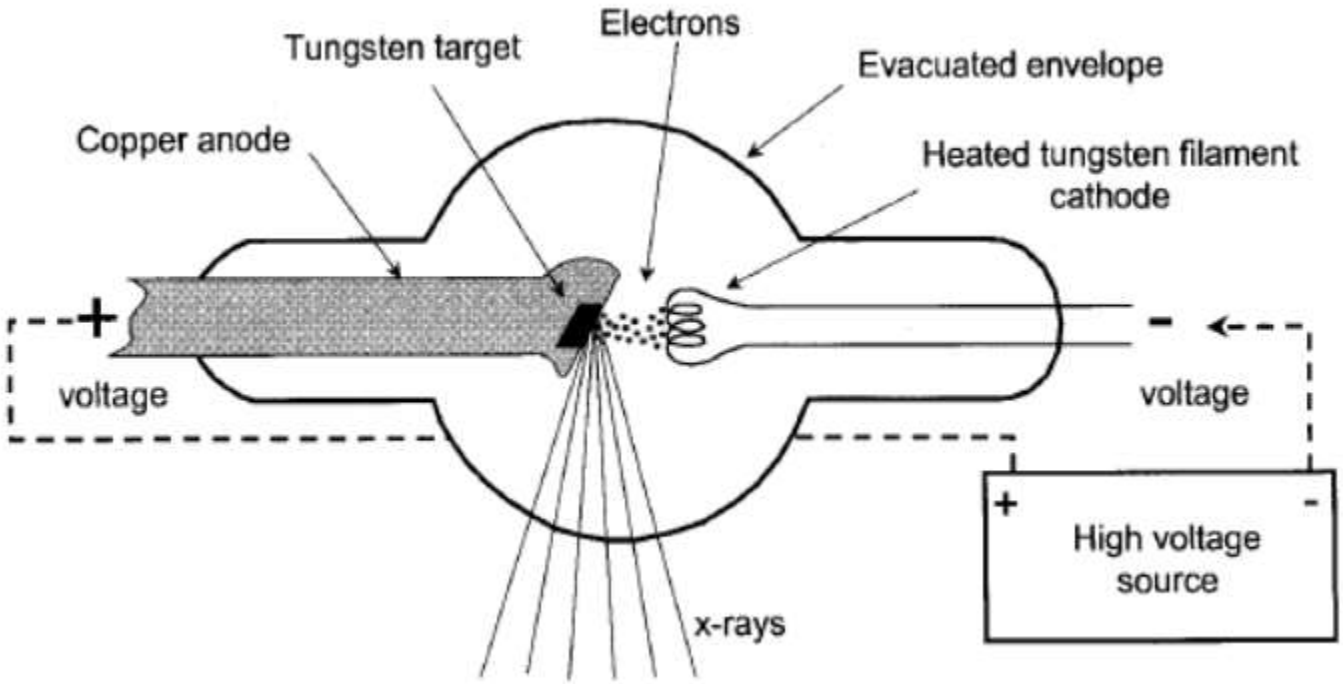
Properties of X-rays

- X-rays are highly penetrating invisible rays.
- They are electrically neutral and can not be deflected by electric or magnetic fields.
- They are capable of ionizing the interacting medium.
- They produce biological and chemical changes in the interacting medium.
- They affect photographic film to produce an image which can be developed chemically.

Basic elements of an X- ray equipment

Basic elements of an X-ray equipment:

- X-ray Generator
- X-ray Tube - Cathode structure, Anode structure
  Focal Spot, Collimator, Tube Housing
- X-ray image receptor
- Couch



X-ray Generator

It is the power circuit supplying the required potential to the X-ray tube.

- It supplies the current to heat the filament of the cathode to emit electrons.
- It supplies the potential to accelerate electrons from cathode to anode.
- The generator also permits control of the x-ray output through the selection of voltage, current and exposure time.

X-ray Tube :

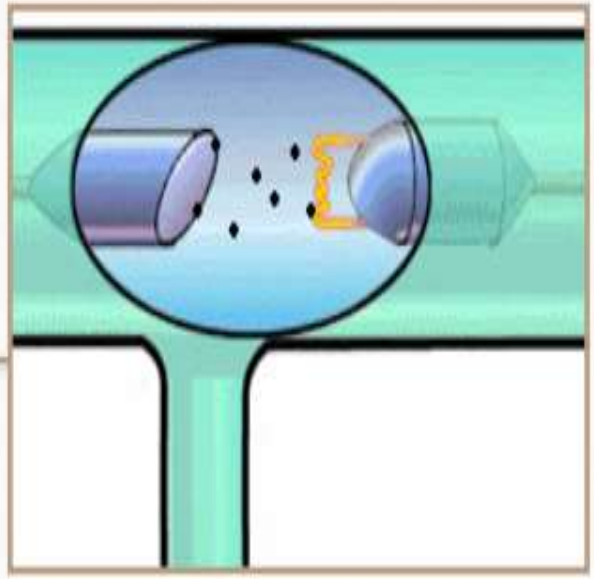
- The X-ray tube provides an environment for X-ray production via bremsstrahlung and characteristic mechanism.

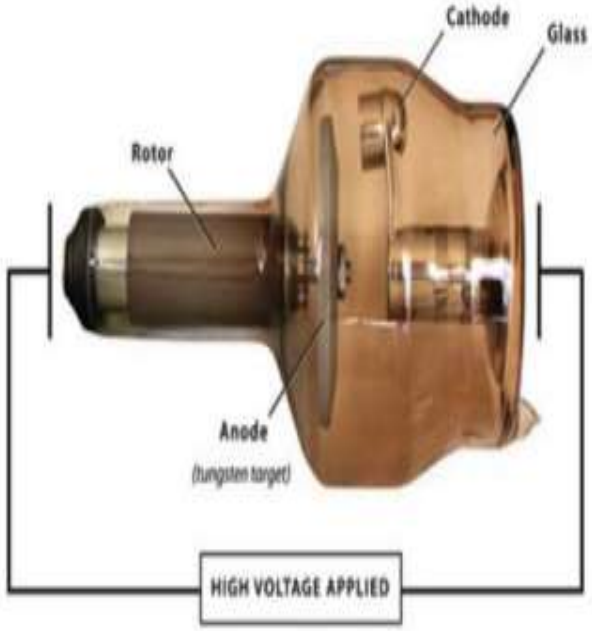
X-ray Tube Components:

- **Cathode**: It contains filament which is the source of the electron beam directed towards the anode.
- **Anode**: It emits X-rays on impacted by electrons.
- **Metal tube housing:** It provides surrounding to glass X-ray tube.
- **Shielding material:** It provides protection against x-rays produced in the direction other than primary beam.

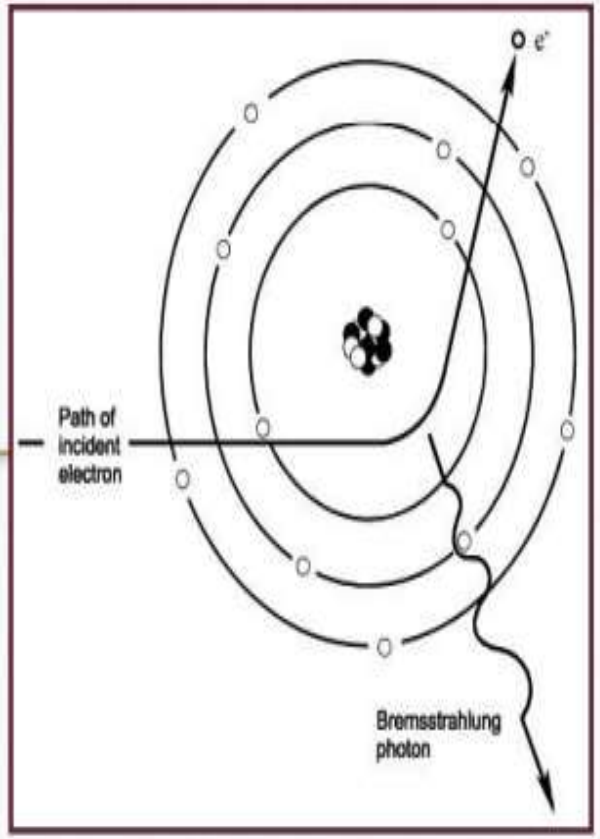
X-ray Production

- X-rays are produced when high energy electrons interact with matter and convert their kinetic energies into electromagnetic radiation.
- The production of an x-ray beam in a clinical imaging system is performed by the x-ray tube. Inside the x-ray tube, an electron beam is generated by liberating electrons from the filament via thermionic emission (heating of the filament).
- Electrons are accelerated towards the anode by applying potential difference between Anode and Cathode. As a result of interaction of electrons with target atoms, electrons transfer its kinetic energy into heat and x-ray photons.





X-ray Production…



X-rays are produced in two ways:

- Production of Bremsstrahlung Radiation
- Production of Characteristic Radiation

Production of Bremsstrahlung Radiation:

When an electron comes within the proximity of a positively charged nucleus of an atom in the target electrode, it decelerates resulting a significant loss of its kinetic energy in the form of x-ray photons. An x-ray photon with energy equal to the kinetic energy lost by the electron is produced (conversion of energy).

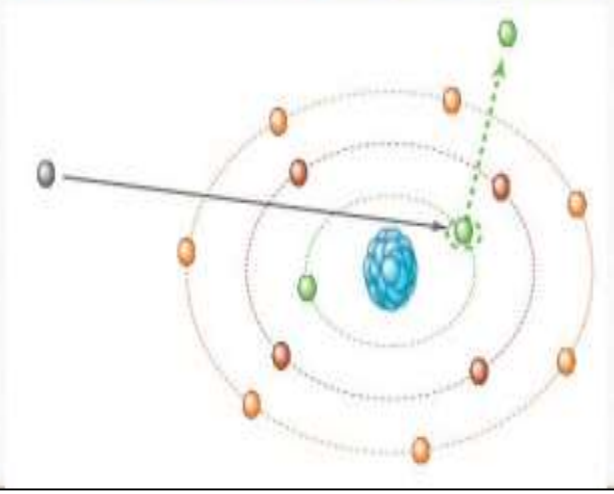
This radiation is termed as **bremsstrahlung**, a German word meaning "braking radiation" or radiation produced from the braking of projectile electrons.

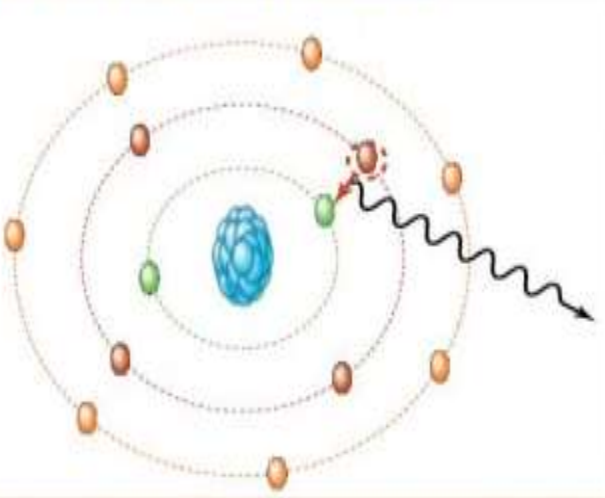
X-ray Production...

Production of Characteristic Radiation:

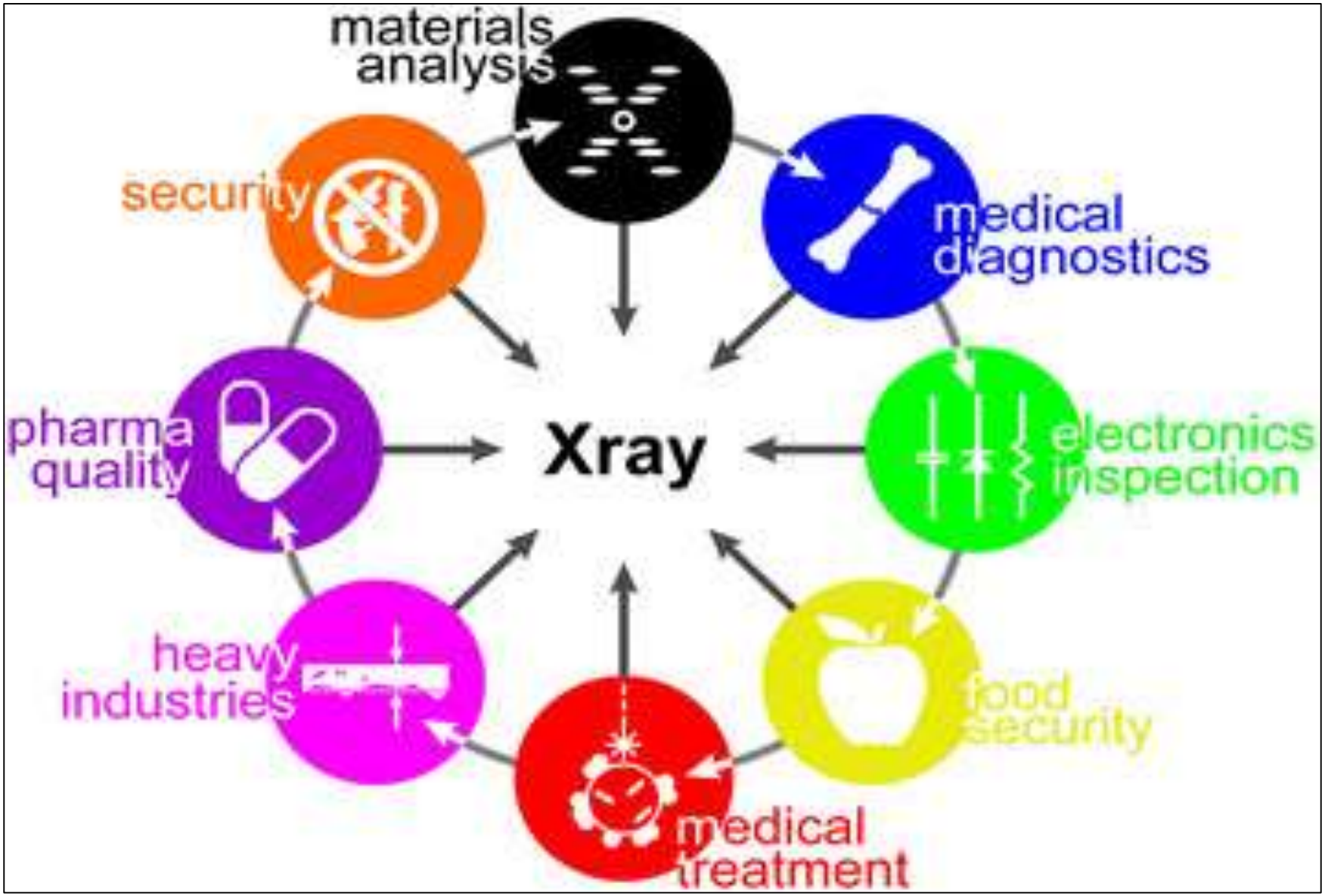
If energy of incident electron is more than binding energy of target atom, the incident electrons may eject electrons from the target atom creating vacancy in the shell. Electrons from higher shells then fill this vacancy, resulting in the emission of **characteristic X-rays**.

As a result of interaction between the electron and the target material, about 99% of the energy is converted into heat and about 1% is converted into X-ray energy.





APPLICATIONS OF X-RAY



X-rays have many uses, including medical imaging, security scanning, and industrial inspection.

Medical uses

- **Bone imaging**: X-rays can help detect broken bones, dislocations, bone infections, arthritis, and bone cancer
- **Cancer screening**: X-rays can help detect breast cancer, and can be used to diagnose and stage other cancers
- **Dental imaging**: X-rays can help detect cavities and tooth decay
- **Imaging of the chest**: X-rays can help detect pneumonia and other chest conditions
- **Imaging of the joints**: X-rays can help detect joint changes and bone damage associated with arthritis
- **Imaging of the intestinal tract**: X-rays can help diagnose conditions in the upper and lower intestinal tract

Security uses

- **Baggage screening**: X-rays can be used to scan luggage in airports and other places

Industrial uses

- **Non-destructive testing**: X-rays can be used to inspect welds, concrete, and other materials for cracks and flaws
- **Restoration**: X-rays can be used to restore old paintings