SAWA UNIVERSITY

اساسيات الفيزياء الشعاعية/ الكورس الاول

CHARACTERISTIC RADIATION

Sawa University — جامعـــــــة ســــــاوة الاهلية

College of health and medical techniques — كليـــــة التقنيـــات الصحيـة والطبيـة

Department of Radiology Tech. — قسم تقنيات الاشعة والسونار

Second Stage — المرحلـــــــــــــة الثانية

الجانب النظري محاضرة رقم (5)

Lecture No. (5) Theoretical

تدريسي المادة : م.م. احمد عكاب شراد

(INTRODUCTION TO CHARACTERISTIC RADIATION)

When high-speed electrons from the cathode strike the anode target of an X-ray tube, they undergo various interactions with the target atoms.One of these interactions is the production of characteristic radiation, which occurs when an incident electron ejects an inner-shell electron (usually from the K-shell) of the target atom.This creates a vacancy, and an electron from an outer shell (such as L or M shell) falls into the vacant position. The difference in binding energies between the two shells is released as an X-ray photon of discrete energy.The term “characteristic” comes from the fact that the photon energy is unique to the atomic structure of the target element.

(MECHANISM OF CHARACTERISTIC RADIATION PRODUCTION)

- When the projectile electron collides with a target atom, sufficient kinetic energy can eject a tightly bound inner-shell electron.
- The atom becomes ionized, leaving an unstable electron configuration.
- An electron from a higher shell transitions downward to fill the vacancy.
- The energy difference between the two levels is emitted as an X-ray photon with discrete energy ($E = E_2 – E_1$).

Example (for tungsten target):

- K-shell binding energy = 69.5 keV.
- L-shell binding energy = 10.2 keV.
- Characteristic photon energy = 69.5 – 10.2 = 59.3 keV

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This photon appears as the Kα line in the X-ray emission spectrum.

(IMPORTANCE IN IMAGING AND DOSE)

Diagnostic Importance:

- Characteristic radiation contributes to **image contrast**, especially at medium to high kVp ranges (above the K-shell binding energy of the target).
- It adds discrete, high-energy peaks to the emission spectrum, which enhance **beam quality** and improve image sharpness.

Dose Implication:

- The presence of characteristic photons slightly **increases patient dose**, as they add more high-energy radiation to the beam.
- Proper filtration and kVp selection minimize excess dose while maintaining adequate image quality.

(INFLUENCE OF ELECTRON ENERGY)

The incident electron energy (kVp) must be greater than or equal to the K-shell binding energy of the target material for characteristic radiation to occur. For example:

- Tungsten requires at least 70 kVp to produce K-shell characteristic X-rays.
- Below this threshold, only Bremsstrahlung radiation is produced.

Effect on Spectrum:

- As electron energy increases above the threshold, more characteristic photons are emitted, increasing the intensity of discrete spectral peaks.
- However, photon energy remains constant for a given material—it depends only on the target atom's binding energies, not the kVp.

(INFLUENCE OF TARGET MATERIAL)

- The atomic number (Z) of the target strongly affects characteristic radiation.
- Higher-Z materials have higher binding energies and therefore produce higher-energy characteristic photons.
- This relationship makes tungsten (Z = 74) ideal for general radiography because it yields strong Kα (~59 keV) and Kβ (~67 keV) lines.
- Molybdenum (Z = 42) is used in mammography for its softer characteristic radiation (~17–19 keV), providing better contrast for soft tissue imaging.

(INFLUENCE OF TARGET MATERIAL)

Target Material	Atomic Number (Z)	Kα Energy (keV)	Typical Application
Tungsten (W)	74	59	General radiography
Molybdenum (Mo)	42	17.4	Mammography
Rhodium (Rh)	45	20.2	Mammography (alternative)
Copper (Cu)	29	8.0	Research and dental X-ray

(INFLUENCE OF FILTRATION)

Function of Filtration:

- Filtration removes low-energy photons from the X-ray beam before it exits the tube.
- Since characteristic radiation photons are of higher, discrete energies, they generally pass through the filter.

Effect on Beam and Dose:

- Filtration slightly reduces the total intensity but increases the average photon energy (beam hardening).
- It selectively removes low-energy Bremsstrahlung photons, improving beam quality and reducing skin dose.
- Proper filtration ensures that characteristic radiation contributes primarily to image formation, not to patient exposure.

(CLINICAL RELEVANCE)

- Characteristic radiation determines image detail, especially in high-contrast studies (e.g., bone imaging).
- Adjusting exposure parameters to maximize useful characteristic X-rays while minimizing dose improves diagnostic safety.
- Understanding these interactions aids radiographers in choosing appropriate imaging parameters for different body regions.

(SUMMARY)

- Characteristic radiation arises from inner-shell electron transitions.
- It produces discrete peaks superimposed on the continuous Bremsstrahlung spectrum.
- Importance: Improves image contrast and contributes to beam quality.
- Influenced by:
  - Electron energy (threshold requirement).
  - Target material (atomic number and binding energy).
  - Filtration (beam hardening and dose control).
- Balancing these parameters ensures optimal image quality with minimal patient dose.

QUIZ

1. CHARACTERISTIC X-RAYS ARE PRODUCED WHEN:

A) ELECTRONS ARE DEFLECTED BY THE NUCLEUS OF THE TARGET ATOM

B) AN OUTER-SHELL ELECTRON FILLS AN INNER-SHELL VACANCY IN THE TARGET ATOM

C) AN ATOM ABSORBS LOW-ENERGY PHOTONS

D) THE ANODE ROTATES DURING EXPOSURE

2. CHARACTERISTIC RADIATION CONTRIBUTES TO DIAGNOSTIC IMAGING BY:

A) PRODUCING A CONTINUOUS X-RAY SPECTRUM

B) REDUCING PATIENT EXPOSURE THROUGH BEAM FILTRATION

C) ADDING DISCRETE, HIGH-ENERGY PHOTONS THAT ENHANCE IMAGE CONTRAST

D) PREVENTING TUBE HEATING DURING EXPOSURE

3. THE MINIMUM TUBE VOLTAGE (KVP) REQUIRED TO PRODUCE CHARACTERISTIC X-RAYS FROM A TUNGSTEN TARGET IS APPROXIMATELY: A) 50 KVP B) 60 KVP C) 70 KVP D) 90 KVP

4. WHICH OF THE FOLLOWING TARGET MATERIALS IS MOST SUITABLE FOR MAMMOGRAPHY, DUE TO ITS SOFTER CHARACTERISTIC RADIATION?

A) TUNGSTEN (W). B) MOLYBDENUM (MO). C) COPPER (CU). D) ALUMINUM (AL)

5. HOW DOES FILTRATION AFFECT CHARACTERISTIC RADIATION IN AN X-RAY BEAM?

A) REMOVES MOST CHARACTERISTIC PHOTONS

B) B) INCREASES THE NUMBER OF CHARACTERISTIC PEAKS

C) ALLOWS HIGHER-ENERGY CHARACTERISTIC PHOTONS TO PASS WHILE REMOVING LOW-ENERGY BREMSSTRAHLUNG PHOTONS

D) HAS NO EFFECT ON BEAM QUALITY OR DOSE

Any questions?

Thank You