INTERACTION OF ELECTRON WITH MATTER

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FUNDEMANTAL OF MEDICAL PHYSICS

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Outline

- Interaction of electrons with matter
- Collisional Interactions
- Radiative Interactions (stopping power)
- Synthesis Routes
- Bottom-Up Approach
- Top-Down Approach
- Applications of Nanomaterials in Medicine and Biology

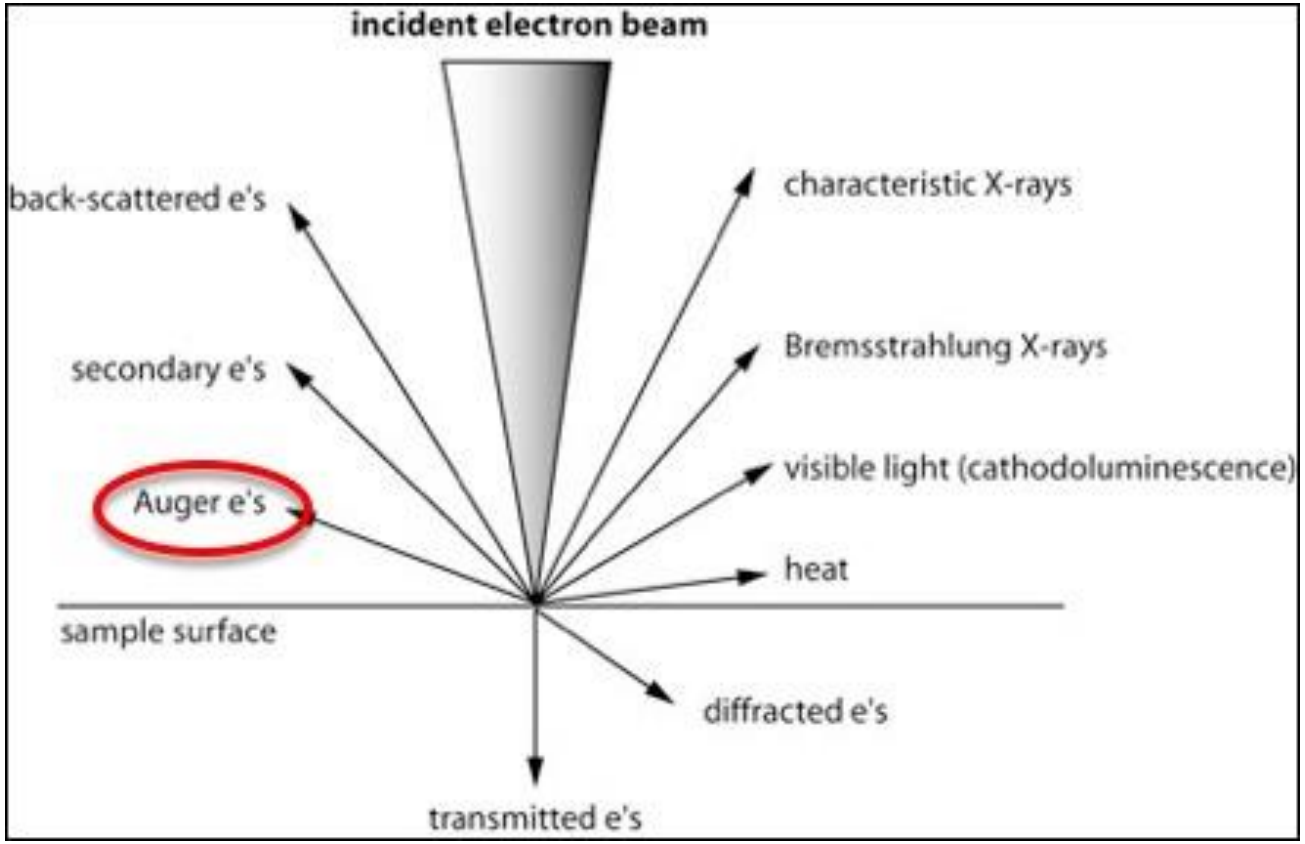
Objectives

The student should be able to explain the followings;

- Interaction of electrons with matter
- Collisional Interactions
- Radiative Interactions (stopping power)
- Synthesis Routes
- Bottom-Up Approach
- Top-Down Approach
- Applications of Nanomaterials in Medicine and Biology

Interaction of Electrons with Matter

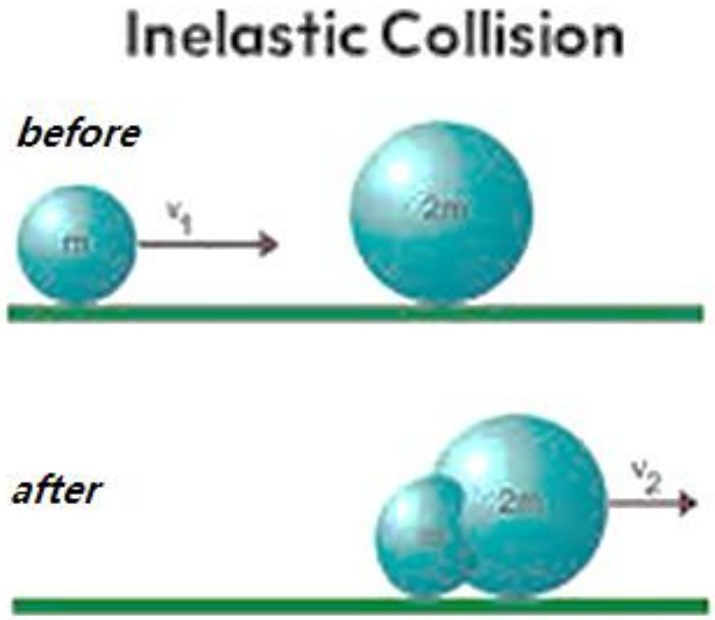
- Electrons interact with matter primarily through electromagnetic forces via Coulomb interactions and photon exchange.
- Electrons have small mass and negative charge, **so**, they undergo rapid scattering, excitation, ionization, and radiative energy loss.

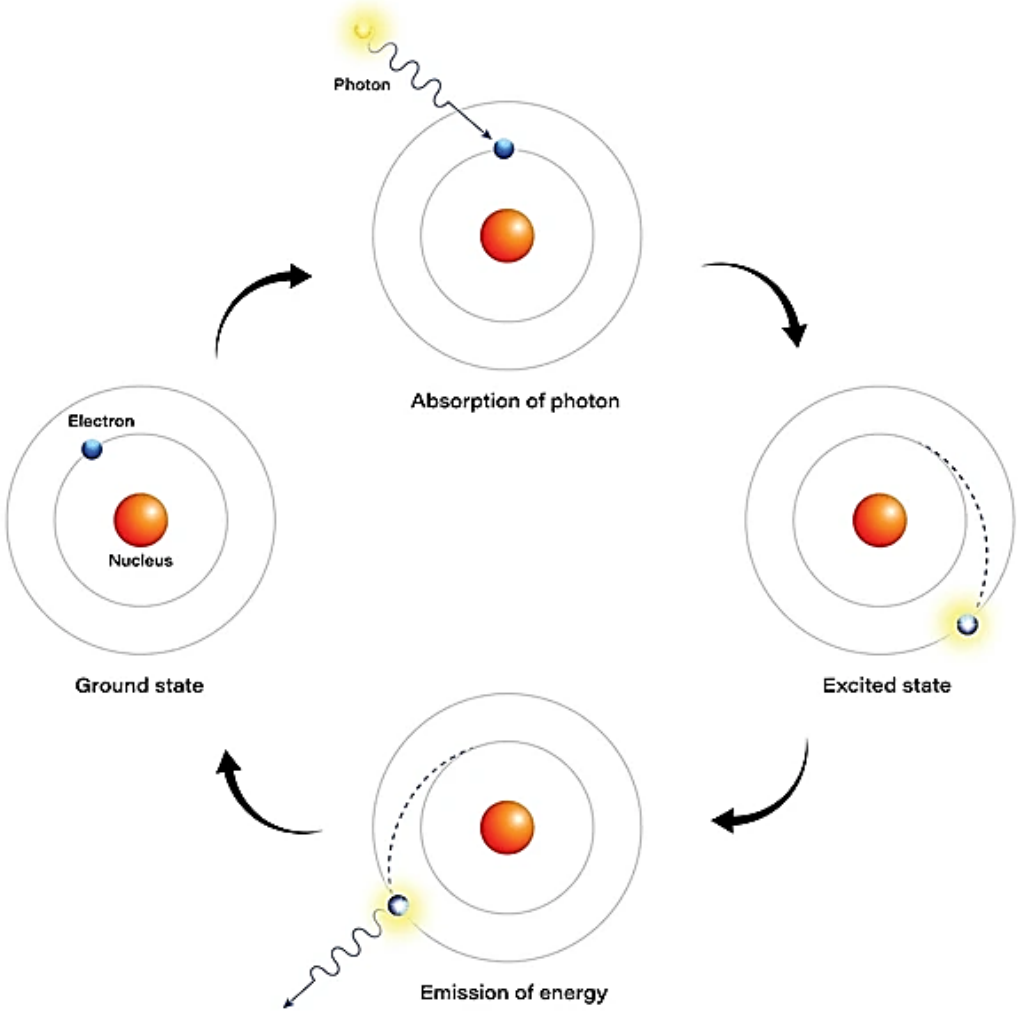


Collisional (Inelastic) Losses

Collisional (Inelastic) Losses:

1- **Excitation:** Incident electrons bump atomic electrons into higher energy shells without ejecting them.

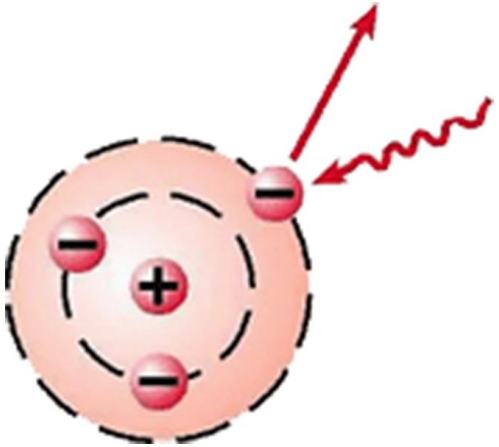


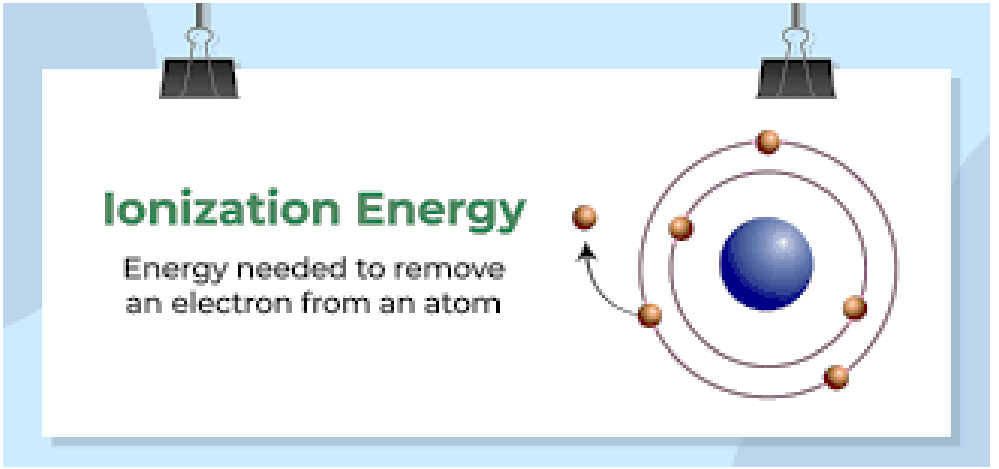


Collisional (Inelastic) Losses

2- Ionization: Incident electrons transfer enough energy to overcome binding energy, ejecting secondary electrons.

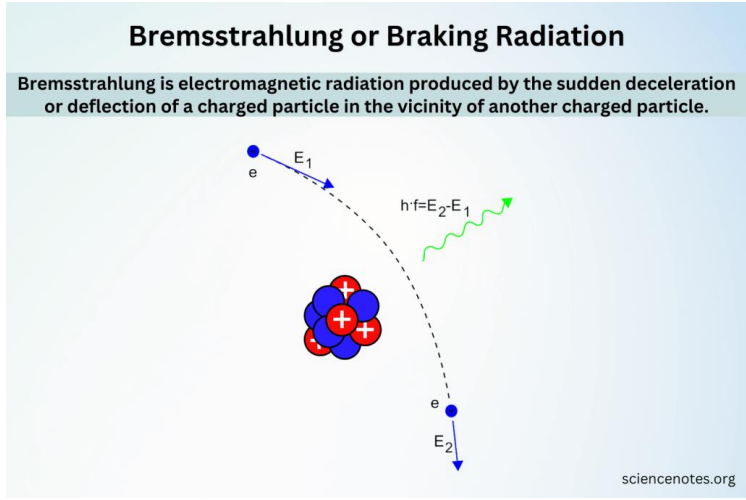
- Mechanism: Coulomb interactions between the incident electron and the orbital electrons of the medium's atoms.
- Outcomes: Excitation (raising an electron to a higher energy state) or Ionization (ejecting an orbital electron, creating secondary electrons).
- Clinical Relevance: This is the primary mechanism for biological damage (destroying cancer cell DNA) in low-Z materials like human tissue.

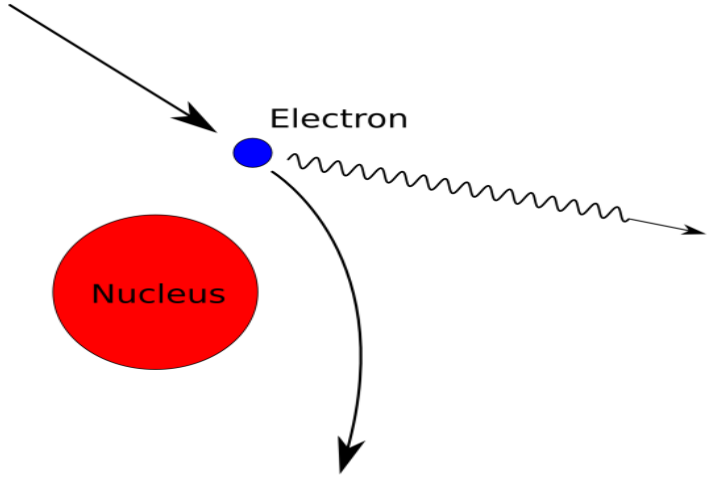




Radiative Losses (Bremsstrahlung)

- **Bremsstrahlung:** As lightweight, negatively charged particles decelerate in the strong electric field of a positive atomic nucleus, they emit braking radiation (X-rays).
- Mechanism: Coulomb interaction between the incident electron and the positive electric field of the atomic nucleus.
- Outcomes: The electron rapidly decelerates and changes direction, emitting braking radiation known as Bremsstrahlung photons (X-rays).

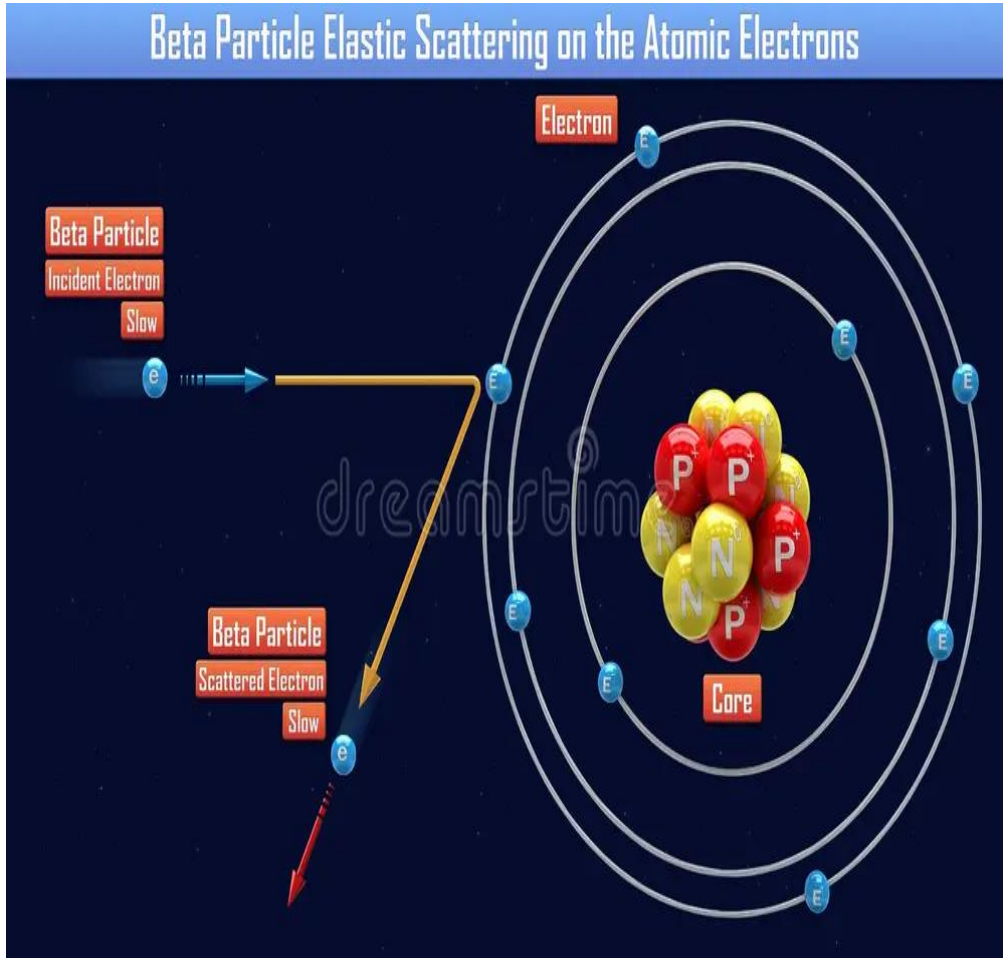




The velocity of the incoming electron is slowed, and the difference in energy is converted into a photon.

Elastic Scattering

- Elastic scattering is a physical process where particles (like photons, electrons, or neutrons) or waves collide with a target and change direction, but their total kinetic energy and wavelength are perfectly conserved.



Total Mass Stopping Power

- Mass Stopping Power ($\frac{S}{\rho}$) is: The rate of energy loss per unit path length (dX) normalized by the density of the medium (ρ)

$$\frac{S}{\rho_{tot}} = \frac{S}{\rho_{col}} + \frac{S}{\rho_{rad}}$$

S: stopping power

- In Tissue (Z ≈ 7.5): Collisional losses dominate at clinical energies. The energy loss rate is relatively constant, averaging roughly 2 MeV/cm in water or soft tissue.
- Collisional losses, showing that S is proportional to the electron density of the medium and decreases as electron velocity increases up to relativistic speeds.

Synthesis Route

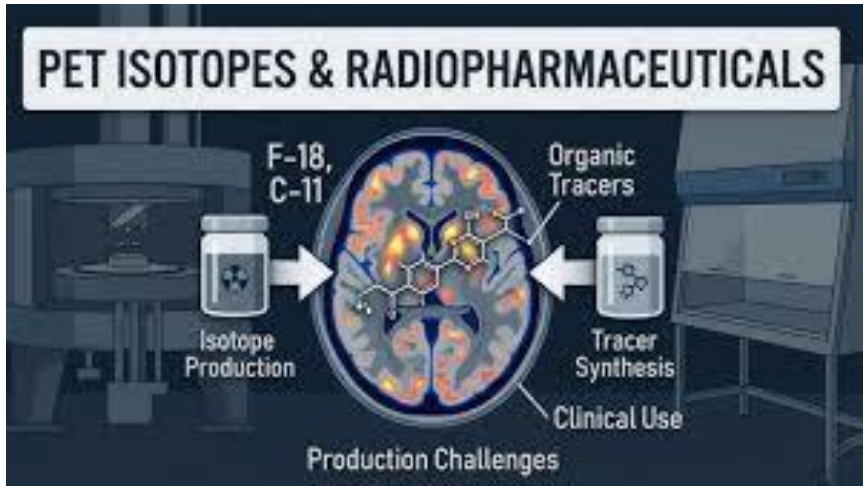
- A synthesis route in chemistry and material science is a step-by-step sequence of chemical reactions mapped out to convert readily available starting materials into a desired target molecule or material.
- The term typically applies to two main clinical categories:

1. Radiopharmaceuticals & Tracer Synthesis
2. Medical Nano-particles

1. Radiopharmaceuticals & Tracer Synthesis

1. **Radiopharmaceuticals & Tracer Synthesis**: In nuclear medicine (PET/SPECT imaging), radiochemists design automated, fast synthesis routes to attach radioactive isotopes to biological molecules before they decay.

Example (^{18}F-FDG): The most common PET tracer.



2. Medical Nanoparticles

2. **Medical Nanoparticles** In advanced radiation therapy and diagnostics (MRI/CT), specific chemical routes are used to synthesize high-Z nanoparticles to enhance imaging contrast or amplify electron-matter interactions (such as boosting localized secondary electron damage to tumors).

Bottom-Up Routes: Building nanoparticles atom-by-atom via chemical reduction, sol-gel processing, or hydrothermal precipitation.

Top-Down Routes: Physically breaking down bulk metallic structures using methods like laser ablation in liquid or sputtering

Applications of Nanotechnology in Biology and Medicine

- Nanotechnology is the branch of science that deals in technology at the scale of nanometers

1- Genetic Engineering: Genetic engineering is making changes in an organism by adding, removing or editing a gene.

2- **Drug Delivery**

3- **Detection, Diagnosis, and Mapping:** Modern diagnostic techniques are mainly focused on detecting biomarkers in a body and determining relationships between them and disease progression.

4- **Cancer Treatment:** Chemotherapy can be targeted and delivered only to cancerous cells, thereby drastically increasing the efficiency of treatment and reducing the side effects associated with it.

5- **Agriculture:** Nanotechnology is used in many ways to improve agricultural production.

References

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