

Medical Imaging and Radiation

Question:

X rays have trouble going through lead because

1. lead is a metal
2. lead is heavy
3. lead atoms have many electrons
4. lead is a hard material

Observations About Medical Imaging and Radiation

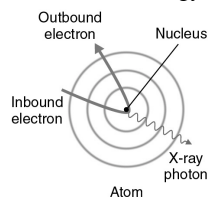
- They manage to work right through your skin
- Imaging involves radiation of various sorts
- Some imaging radiation is itself hazardous
- Radiation can directly make you well, sick, or neither
- Some radiation involves radioactivity
- Some radiation involves accelerators

X rays

- Short-wavelength electromagnetic waves
- An x-ray photon has lots of energy
 - Enough to do much chemical damage to molecules
 - Enough to knock particles out of atoms
- Produced by energetic events
 - Rapid acceleration of a charge
 - Radiative transition in a highly excited atom

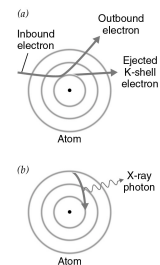
Bremsstrahlung X rays

- When a fast-moving electron swings around a heavy nucleus, it accelerates rapidly
- Electron emits much of its energy as X-ray photon



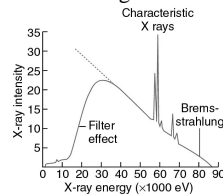
Characteristic X-rays

- When a colliding electron excites an atom to high-energy state, that atom can then radiate an x-ray photon



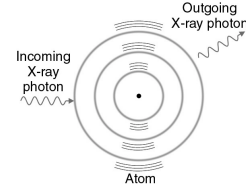
Producing X-rays

- Accelerate electrons to 10kV - 100kV
- Let electrons hit heavy atoms
- Some x-rays emitted via bremsstrahlung and some as characteristic X rays
- X-ray tube filters away lowest energy photons, which is good because they're useless and burn



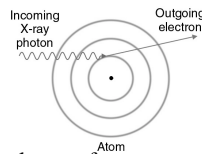
X rays and Matter

- X rays interact with atoms
 - Rayleigh scattering
 - Photoelectric effect
- Rayleigh scattering makes the sky blue and deflects X rays



Photoelectric Effect

- X ray causes radiative transition in an atom and ejects an electron
- Electron's energy is the difference between the x-ray photon's energy and the energy needed to remove electron from atom
- Effect is most likely when electron energy is low
- Effect is strongest in many-electron atoms

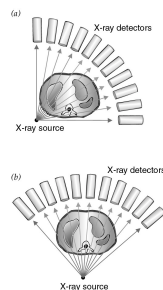


X-ray Imaging

- Any atom that blocks X rays casts a shadow
 - Many-electron atoms produce shadows
 - Few-electron atoms cast essentially no shadows
- All atoms Rayleigh scatter X rays, causing haze
- X-ray imaging observes shadows of large atoms
- Haze can be filtered by collimating structures

CT Scanning

- Many separate X-ray images produce CT database
 - X rays from different angles mix shadows differently
- Computer can recreate original 3-D from database
- Computer typically plots cross sections



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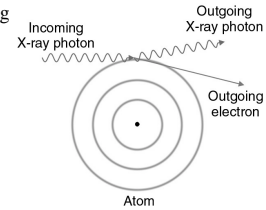
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Gamma Rays

- Higher photon energy than X rays
- Sources
 - Radiative transitions in nuclei
 - Particle accelerators (high-energy bremsstrahlung)

Gamma-rays and Matter

- Gamma rays interact with individual charges
 - Compton scattering
 - Pair production



Radiation Therapy

- Gamma rays are highly penetrating in tissue
- Little Rayleigh scattering and photoelectric effect
- Most gamma ray events are Compton or Pair Prod.
- Either event damages many molecules
- Gamma radiation kills cells
- Approaching tumors from many angles minimizes collateral damage to healthy tissue

MRI Imaging

- Hydrogen nuclei are protons
- Protons are magnetic
- In a magnetic field, spin-up and spin-down protons have different energies
- Radio wave photons can flip the proton spins
- By controlling the energy differences between spin-up and spin-down and adjusting the radio waves, you can locate hydrogen in a person