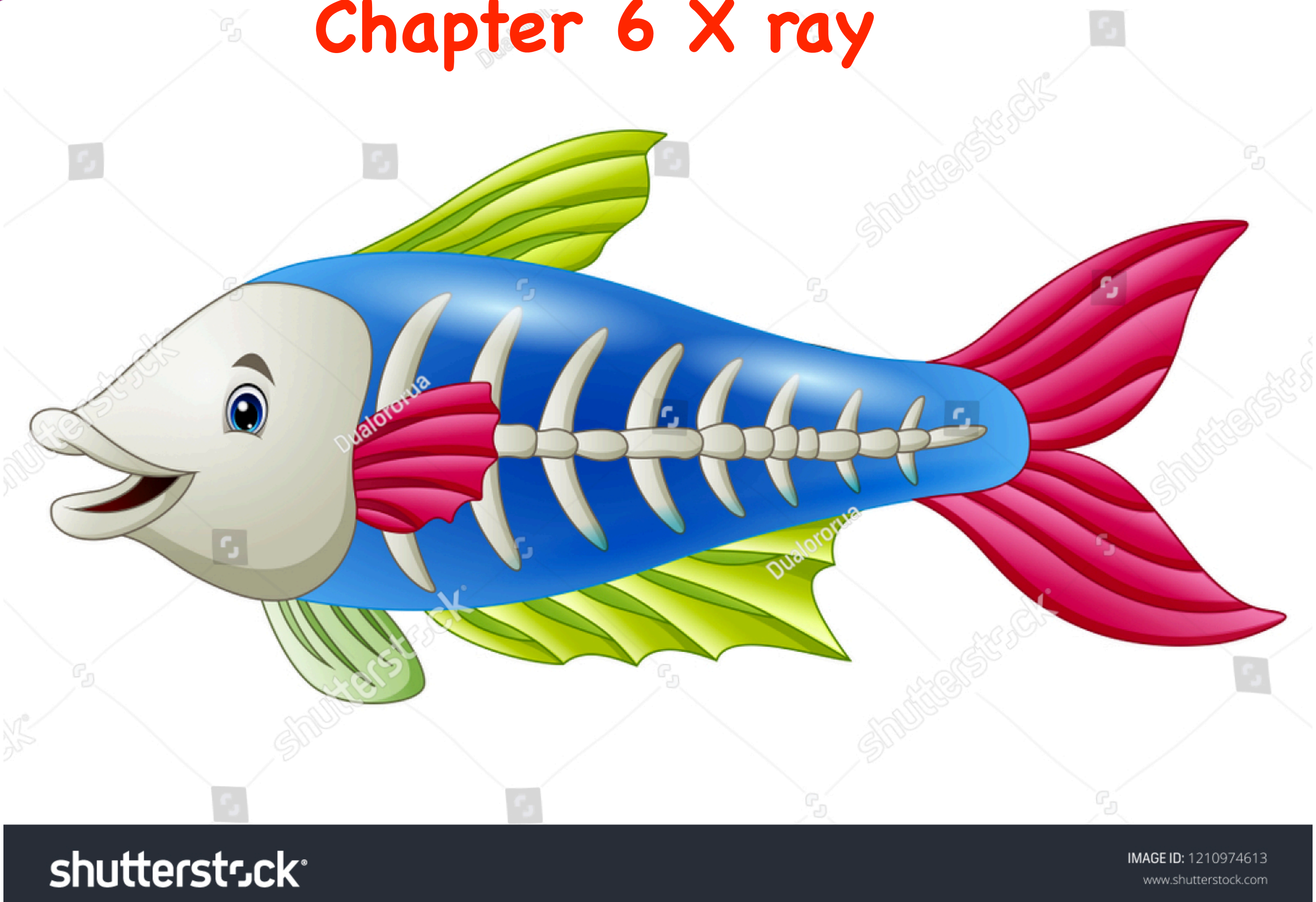
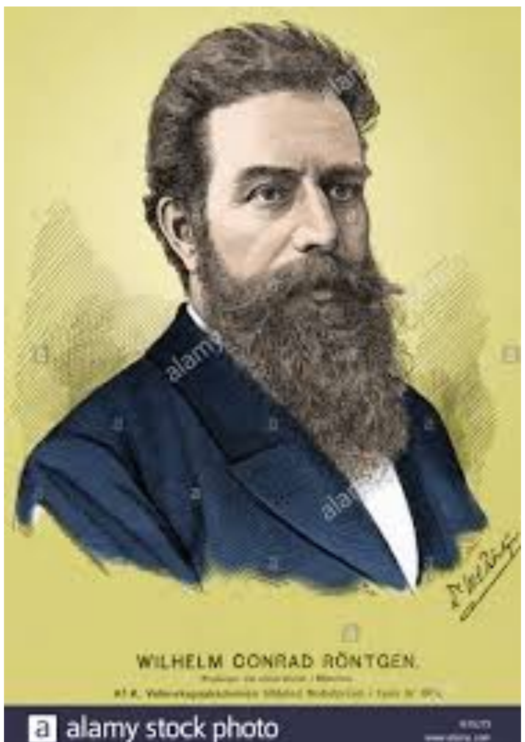
Atomic Physics

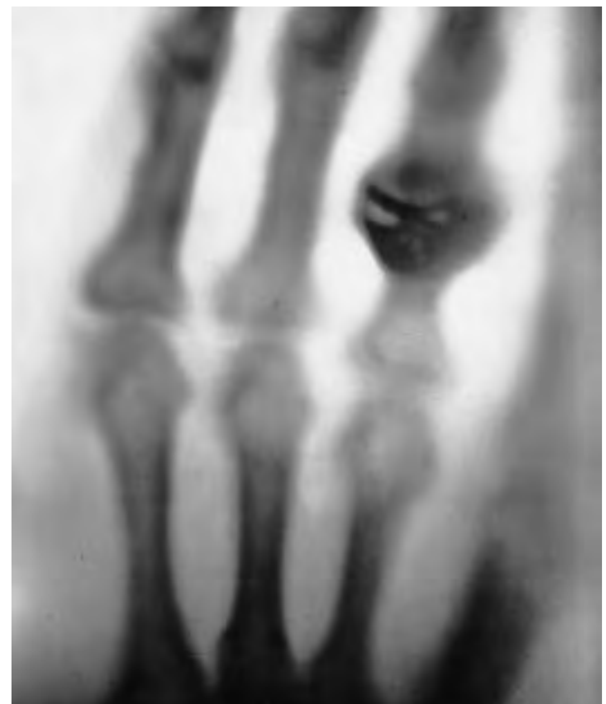
Chapter 6 X ray



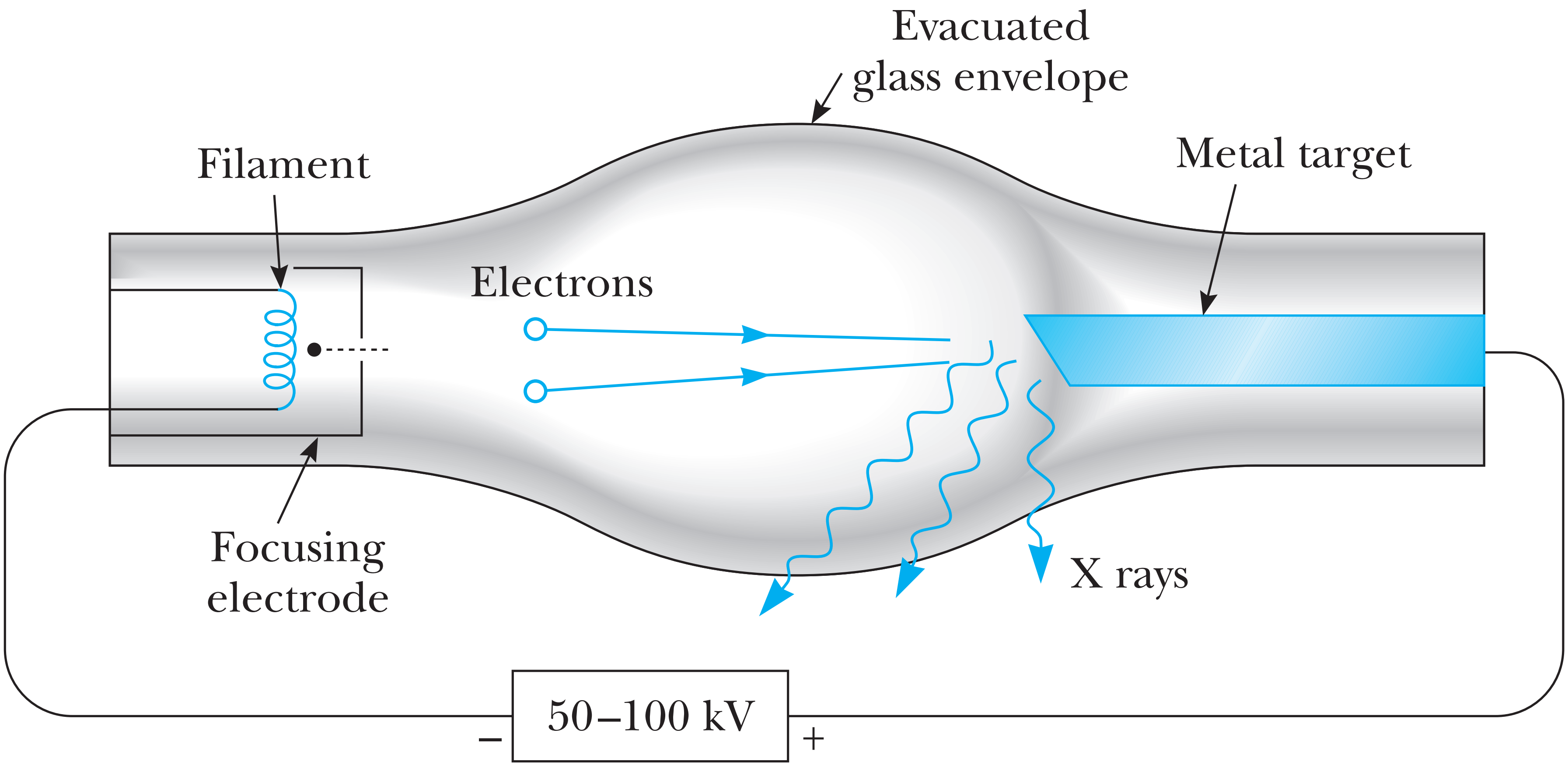
6.1 The discovery of X ray

X-rays were discovered in 1895 by the German physicist Wilhelm Roentgen. He found that a beam of high-speed electrons striking a metal target produced a new and extremely penetrating type of radiation.

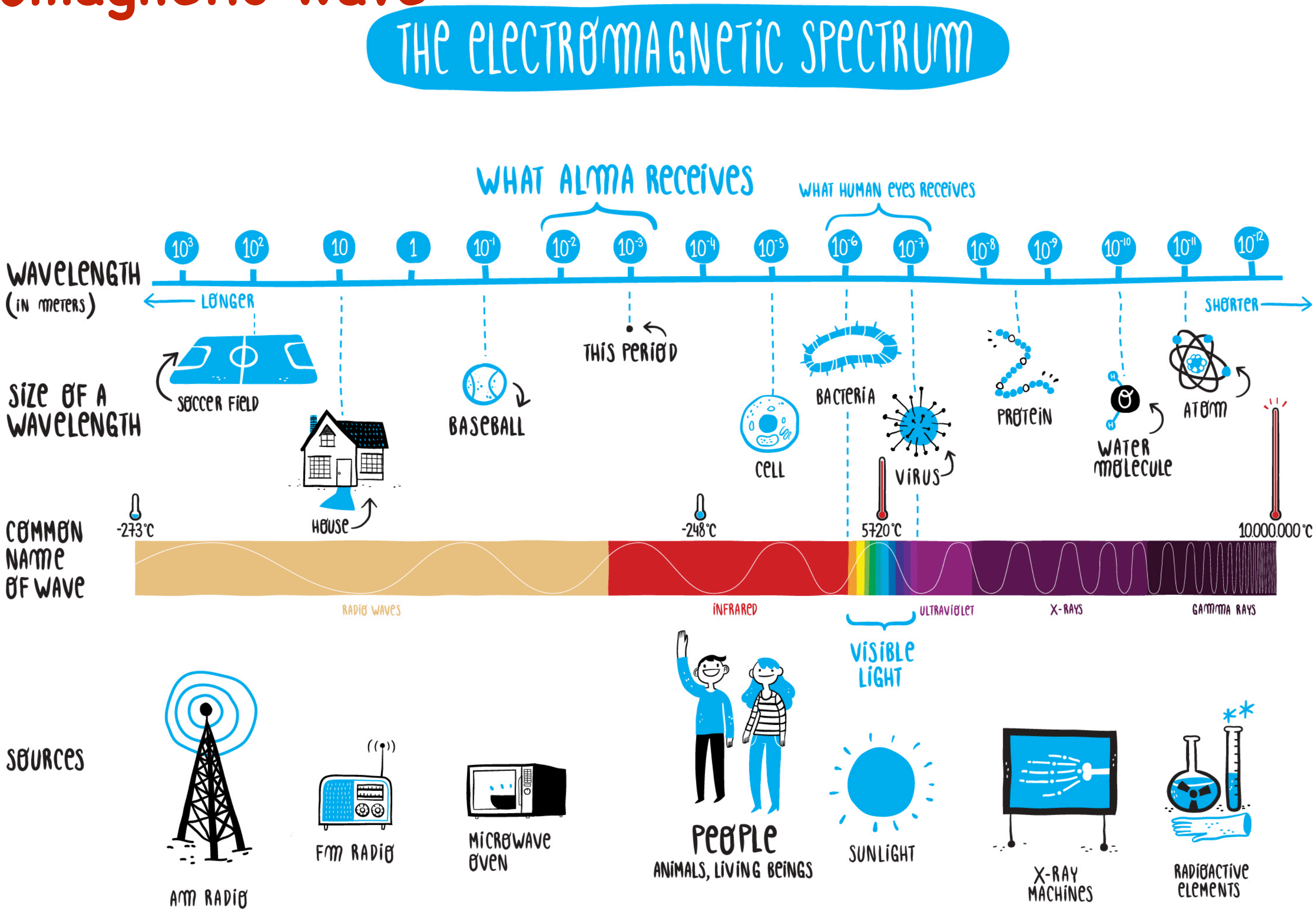




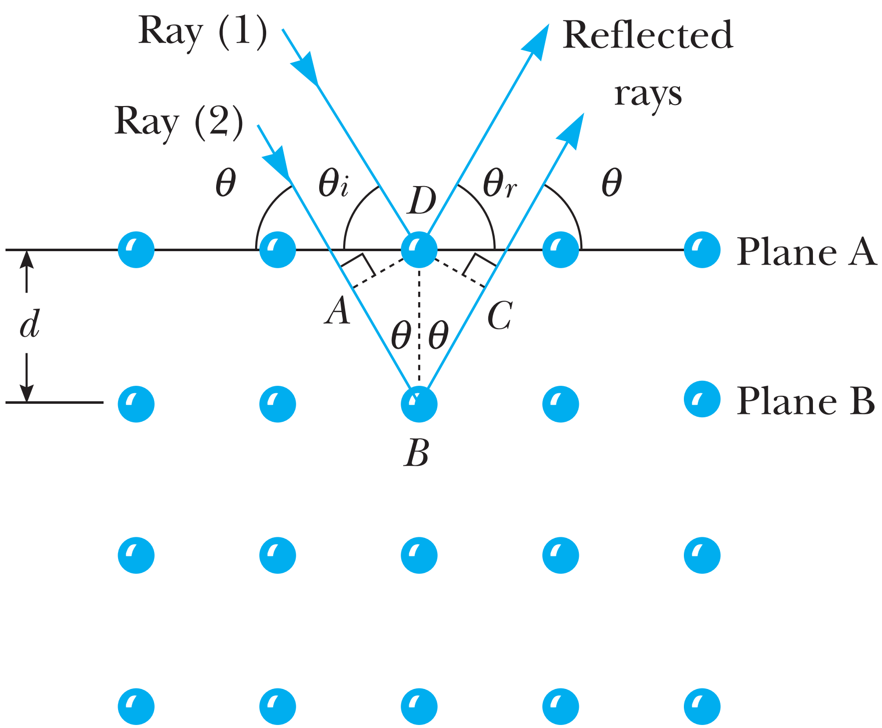
X-rays Tube


Evacuated
glass envelope
Filament
Metal target
Electrons
Focusing
electrode
X rays
50–100 kV
−
+

Electromagnetic wave

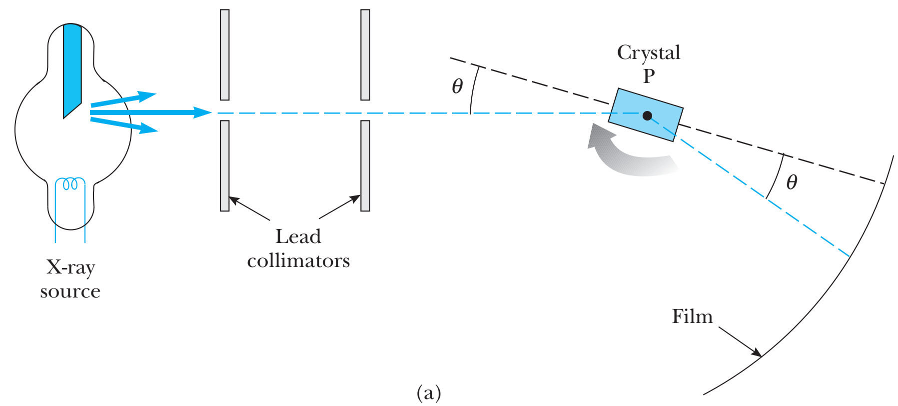


X ray diffraction

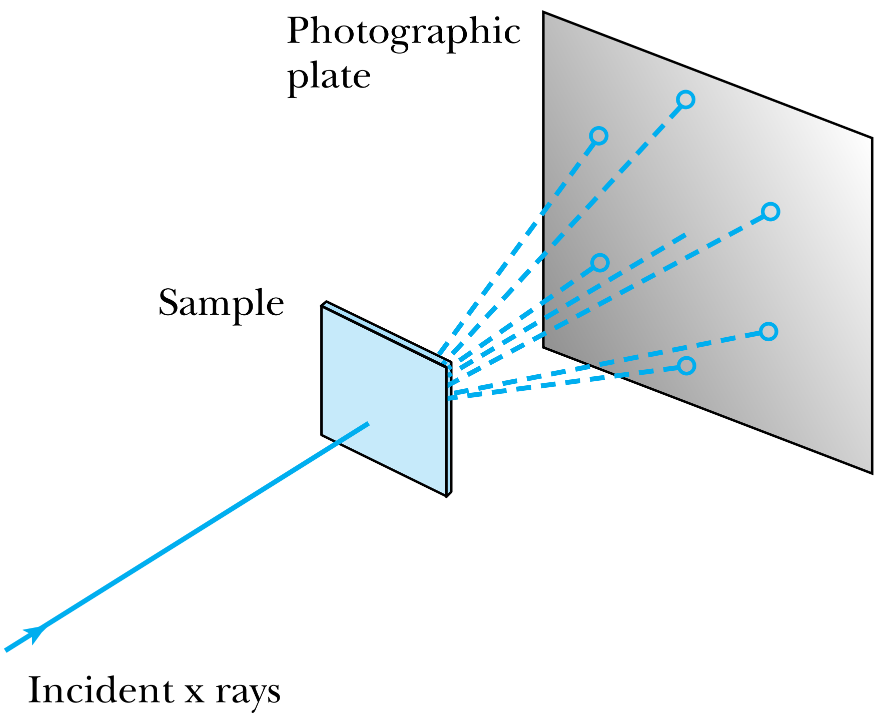


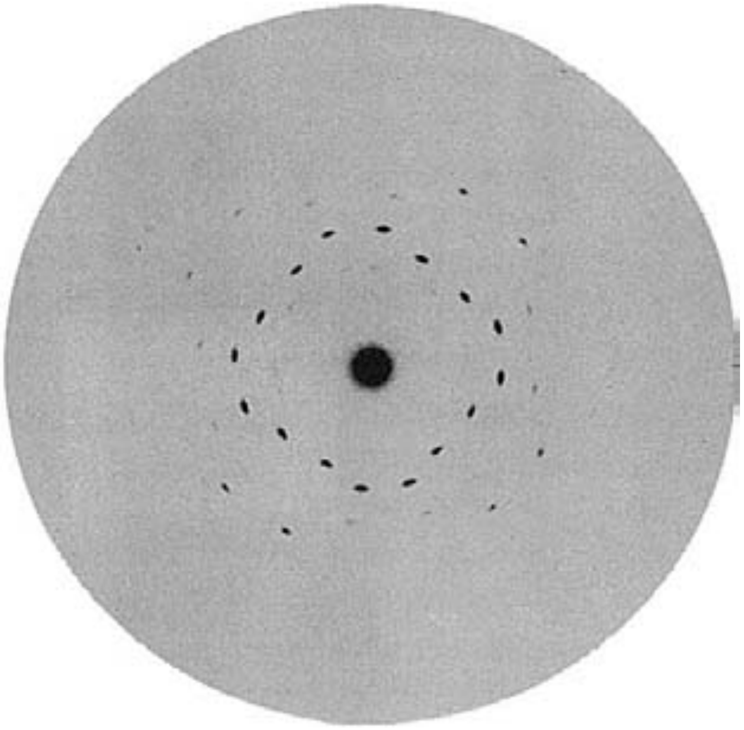
Bragg equation

$$n\lambda = 2d \sin \theta \qquad n = 1, 2, 3, \ldots$$



Laue diffraction transmission method



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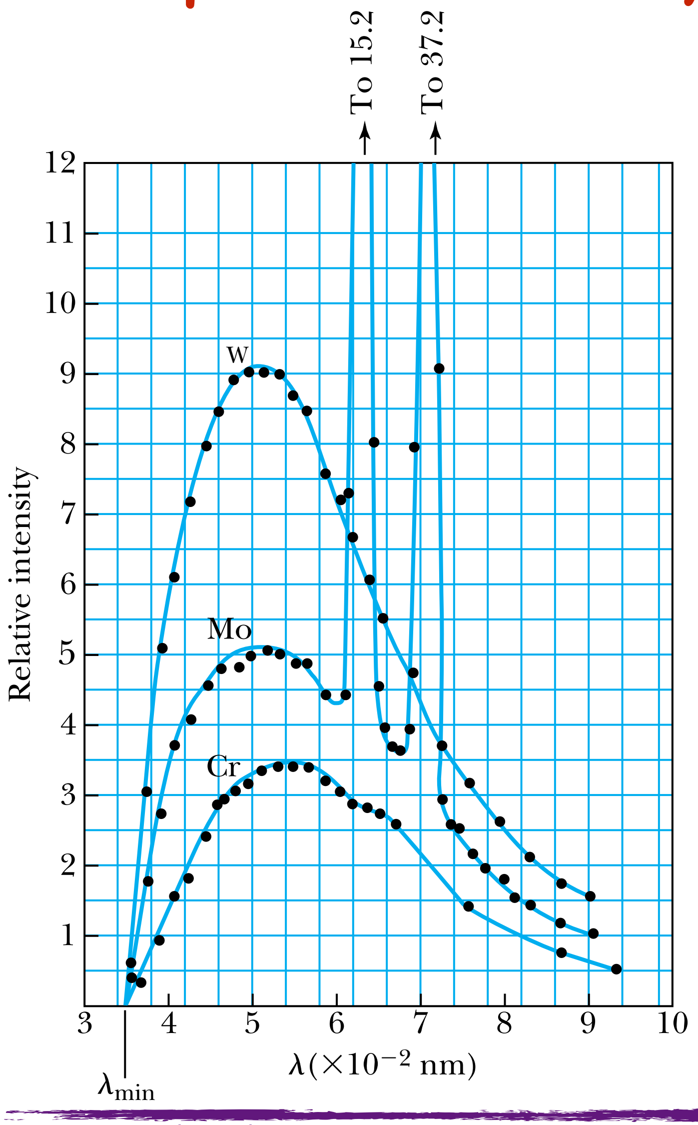
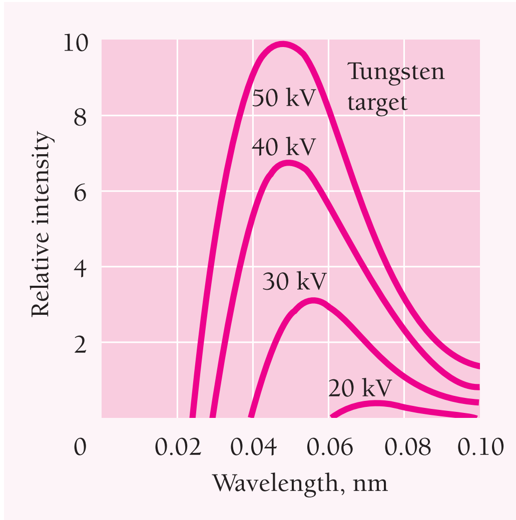
6.2 X ray production

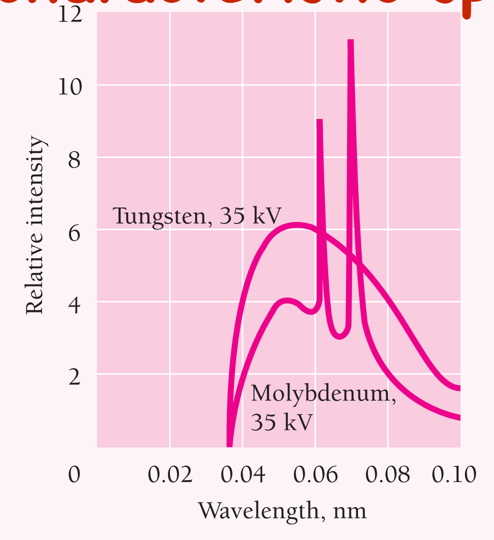
The spectrum of X ray



The continuous spectrum

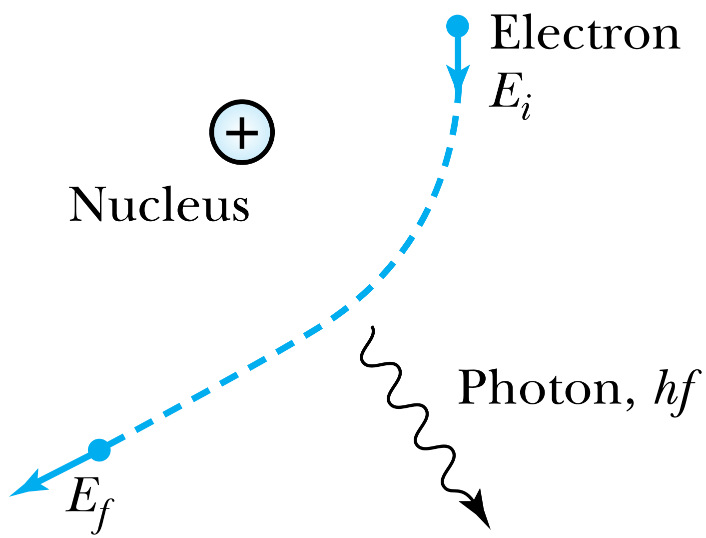


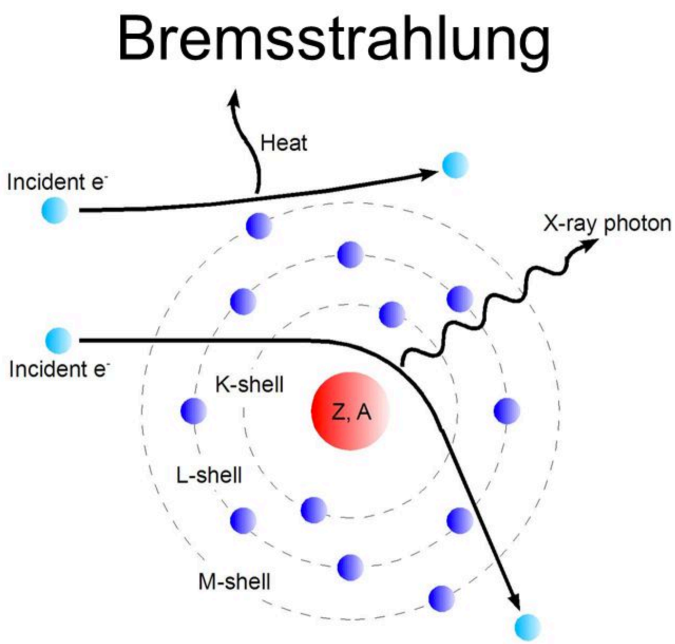
The characteristic spectrum



The continuous spectrum:

An energetic electron passing through matter will radiate photons and lose kinetic energy. The process by which photons are emitted by an electron slowing down is called bremsstrahlung, from the German word for "braking radiation."





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The minimum wavelength is due to the inverse photoelectric effect. The conservation of energy requires that the electron kinetic energy equal the maximum photon energy:

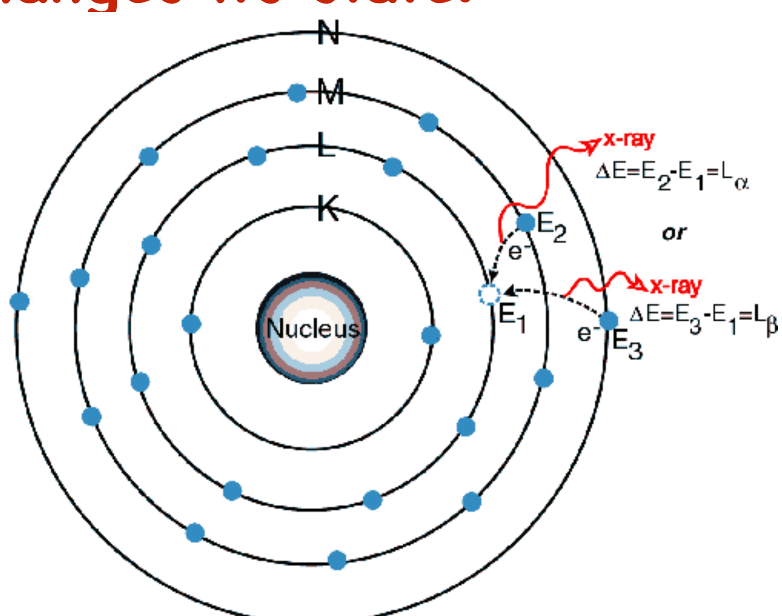
$$eV_0 = hf_{\max} = \frac{hc}{\lambda_{\min}}$$

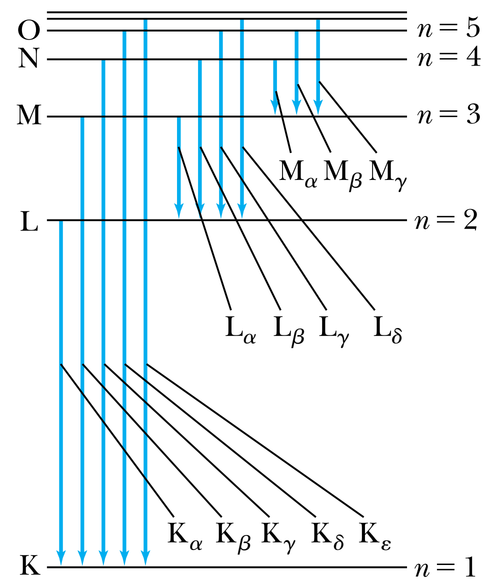
Therefore, the minimum wavelength (Duane-Hunt rule) is

$$\lambda_{\min} = \frac{hc}{e}\frac{1}{V_0} = \frac{1.240 \times 10^{-6}\,\mathrm{V \cdot m}}{V_0}$$

The characteristic spectrum:

The atom is most stable in its lowest energy state or ground state, so it is likely that N an electron from one of the higher shells will change its state and fill the inner-shell vacancy at lower energy, emitting radiation as it changes its state.





6.2 X ray production

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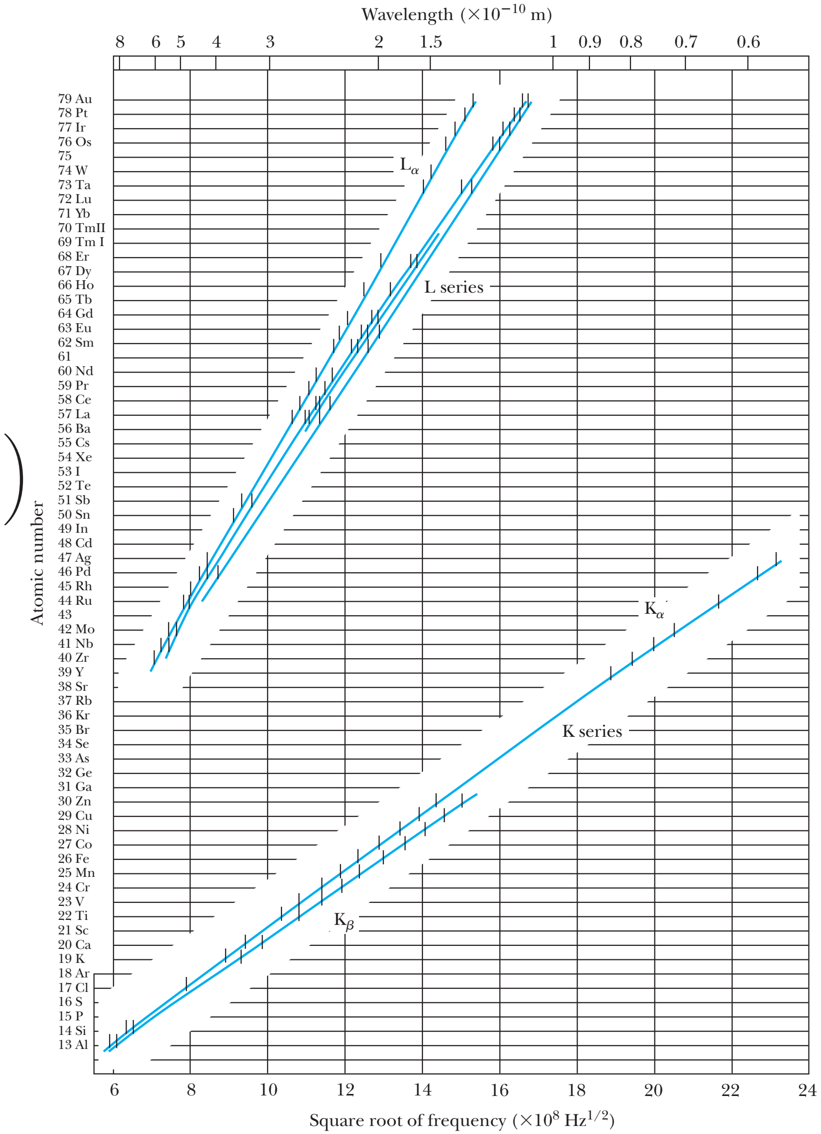
Moseley formula

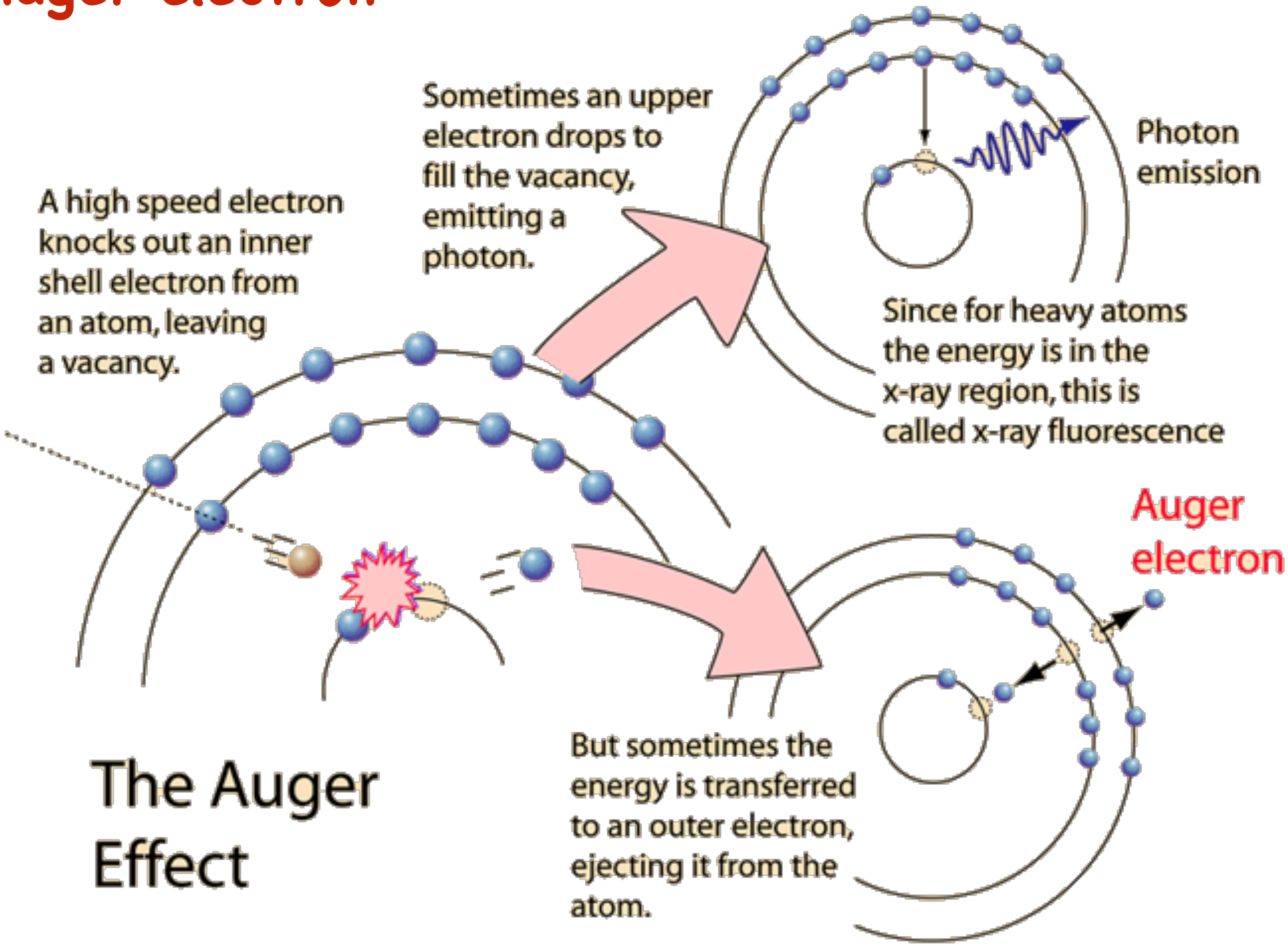
$$\frac{1}{\lambda_{K_\alpha}} = R(Z-1)^2\left(\frac{1}{1^2}-\frac{1}{2^2}\right) = \frac{3}{4}R(Z-1)^2$$

$$f_{K_\alpha} = \frac{c}{\lambda_{K_\alpha}} = \frac{3cR}{4}(Z-1)^2$$

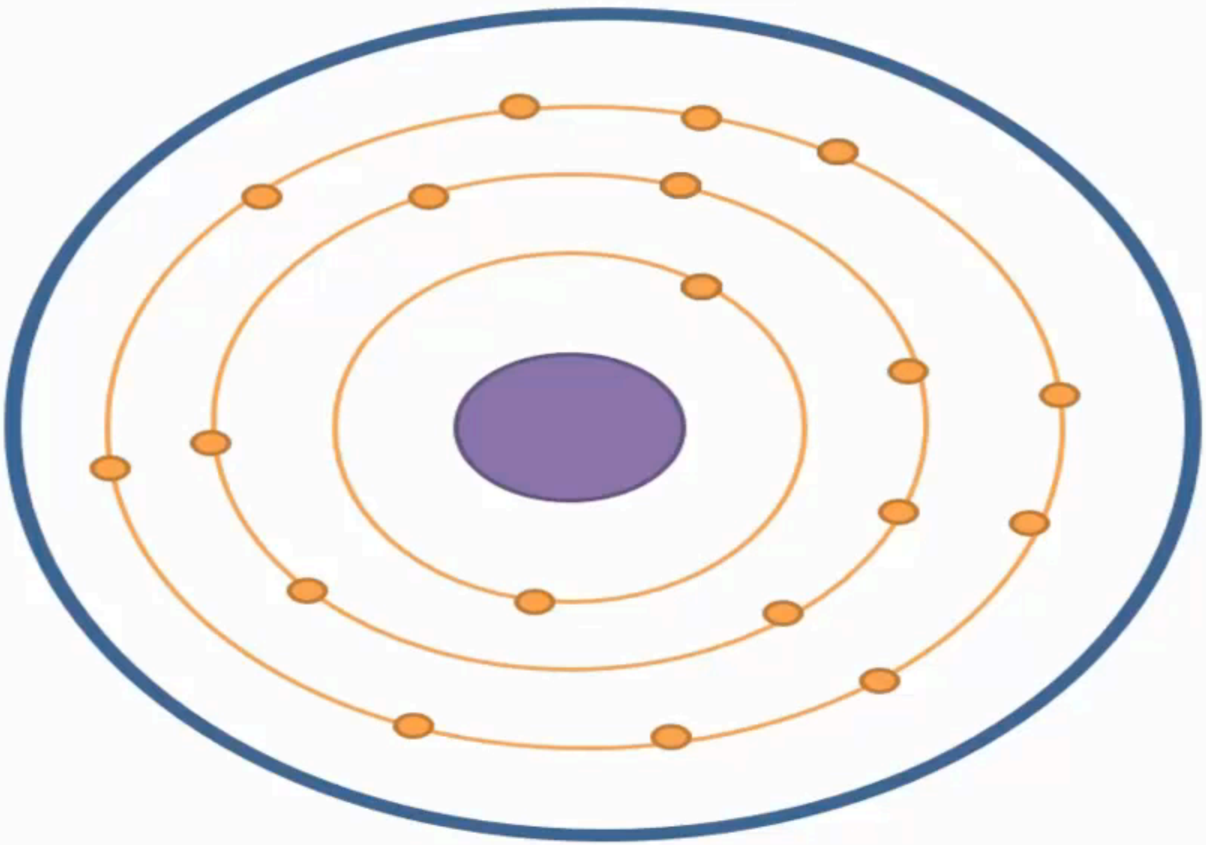
$$\frac{1}{\lambda_K} = R(Z-1)^2\left(\frac{1}{1^2}-\frac{1}{n^2}\right) = R(Z-1)^2\left(1-\frac{1}{n^2}\right)$$



Auger electron



AUGER EFFECT OR AUGER PROCESS



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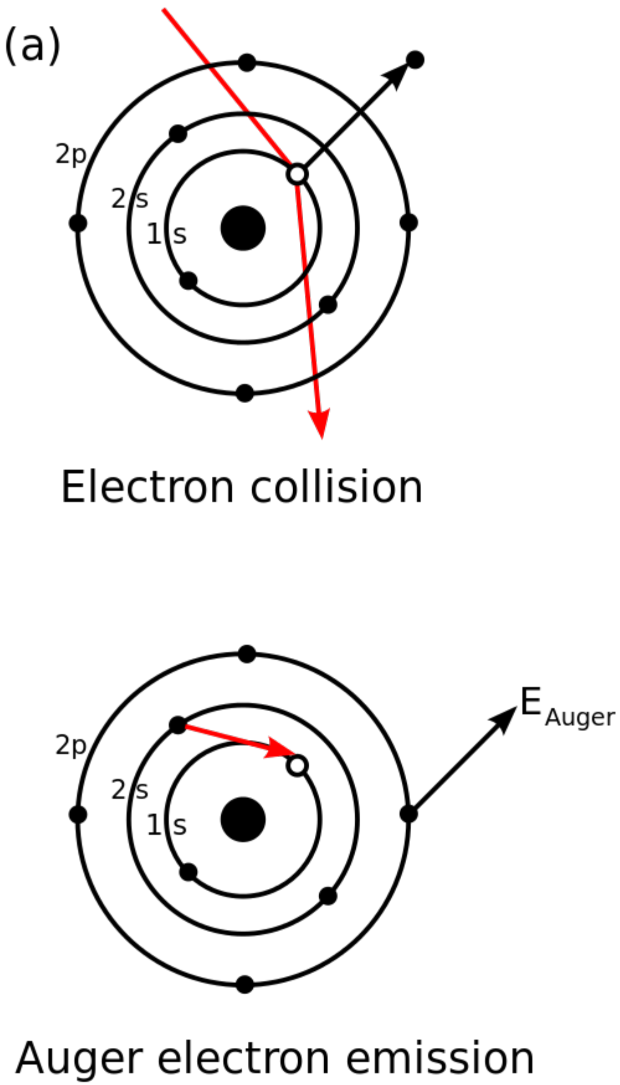
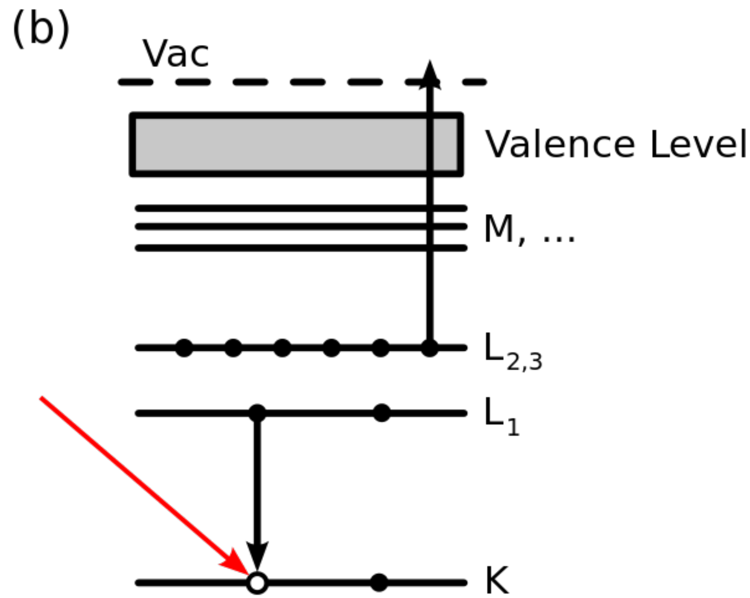
Auger electron

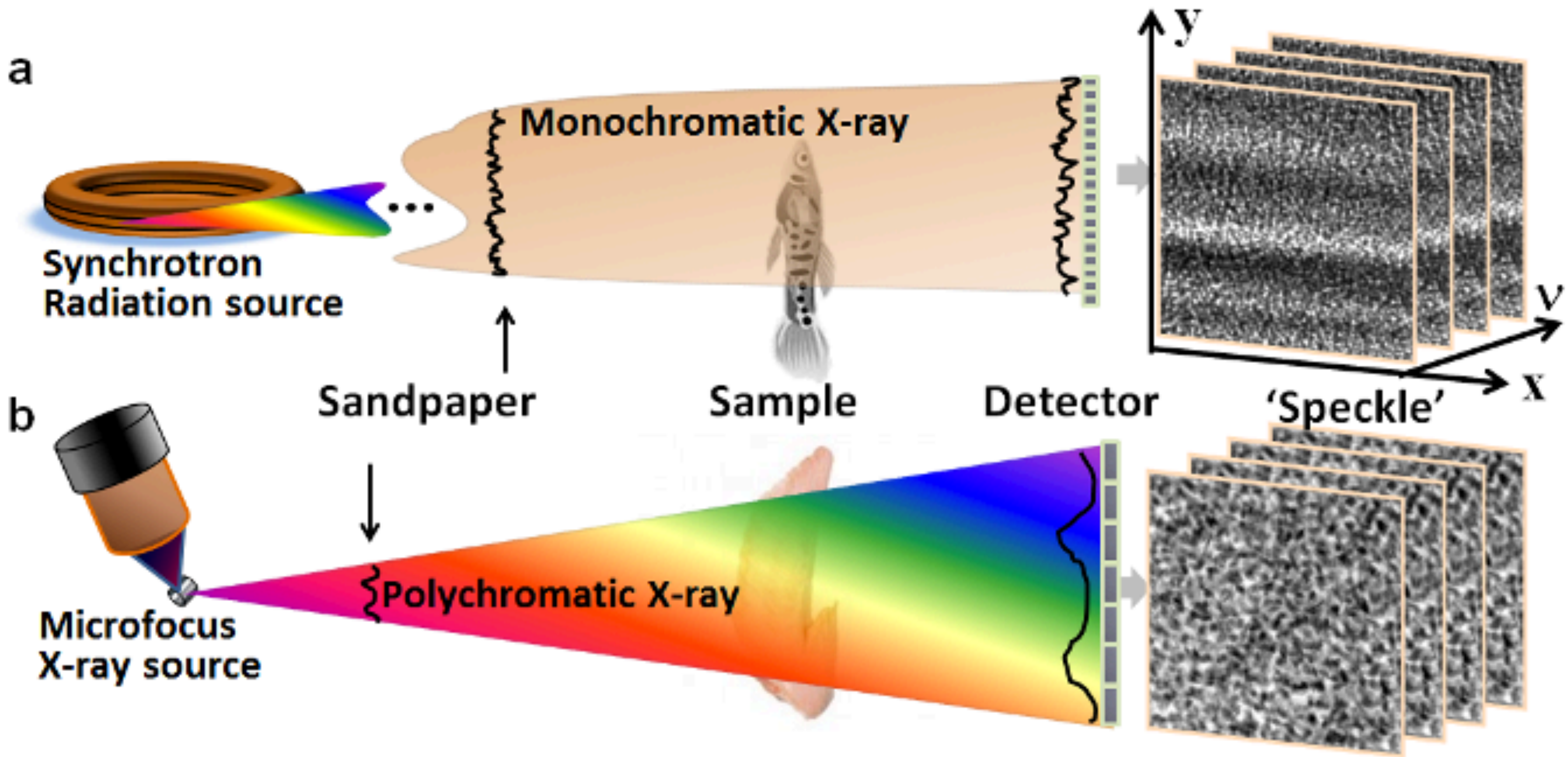




The kinetic energy of Auger electron

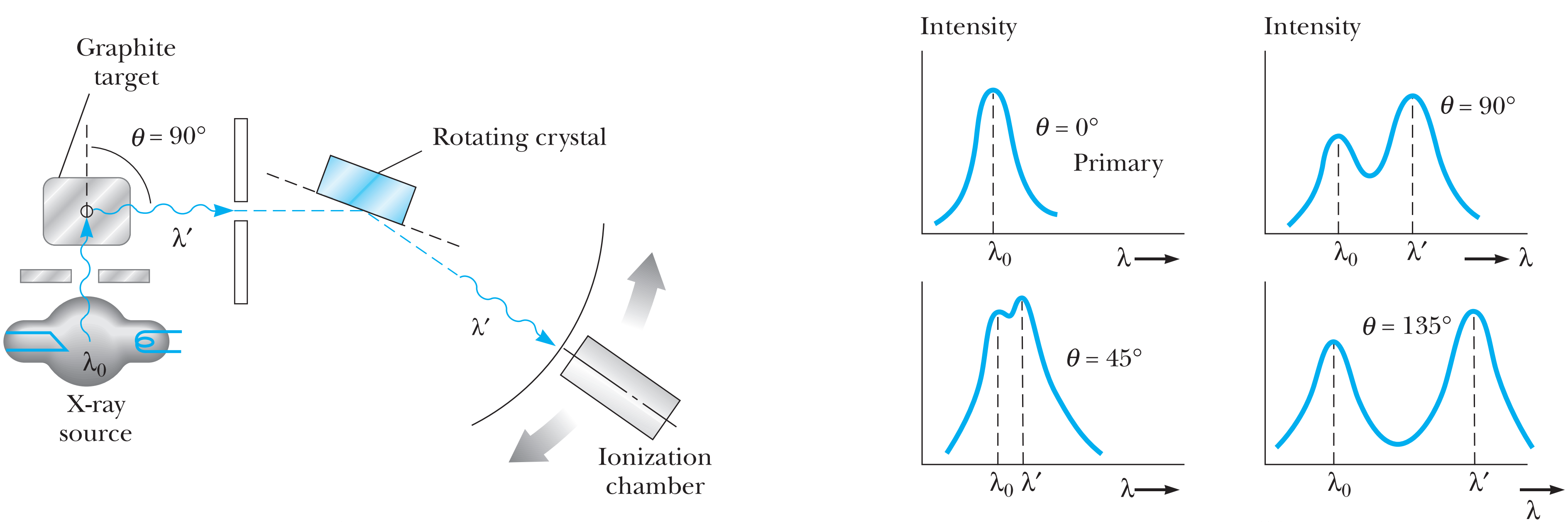
$$E_{ae} = E_K - E_{L_1} - E_{L_{2,3}}$$

Synchrotron Radiation: In cyclic accelerators, when charged particles are accelerated, they radiate electromagnetic energy called synchrotron radiation.



6.3 Compton scattering

At backward-scattering angles, there appeared to be a component of the emitted radiation (called a modified wave) that had a longer wavelength than the original primary (unmodified) wave.



(a) (b)

6.3 Compton scattering

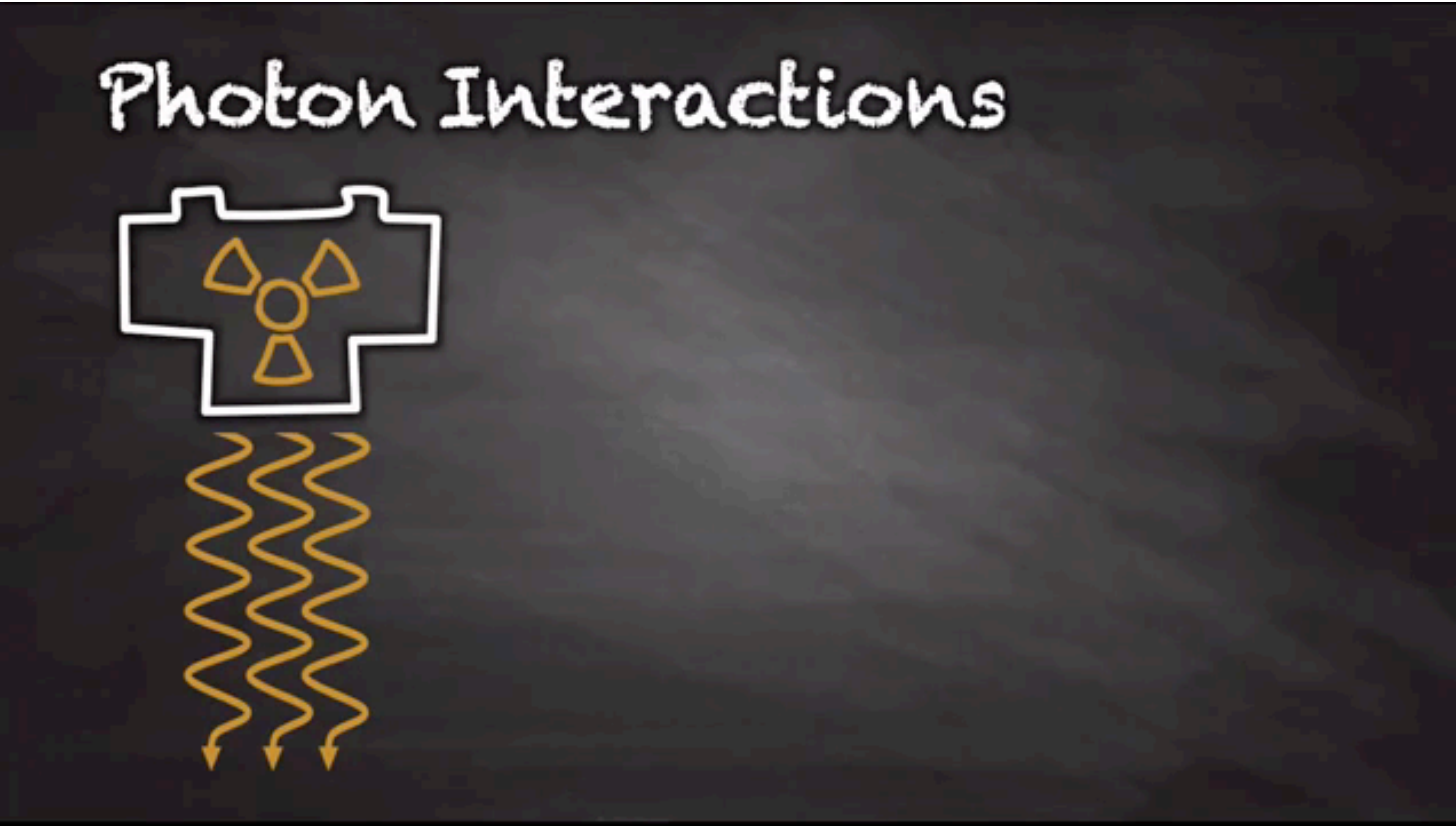
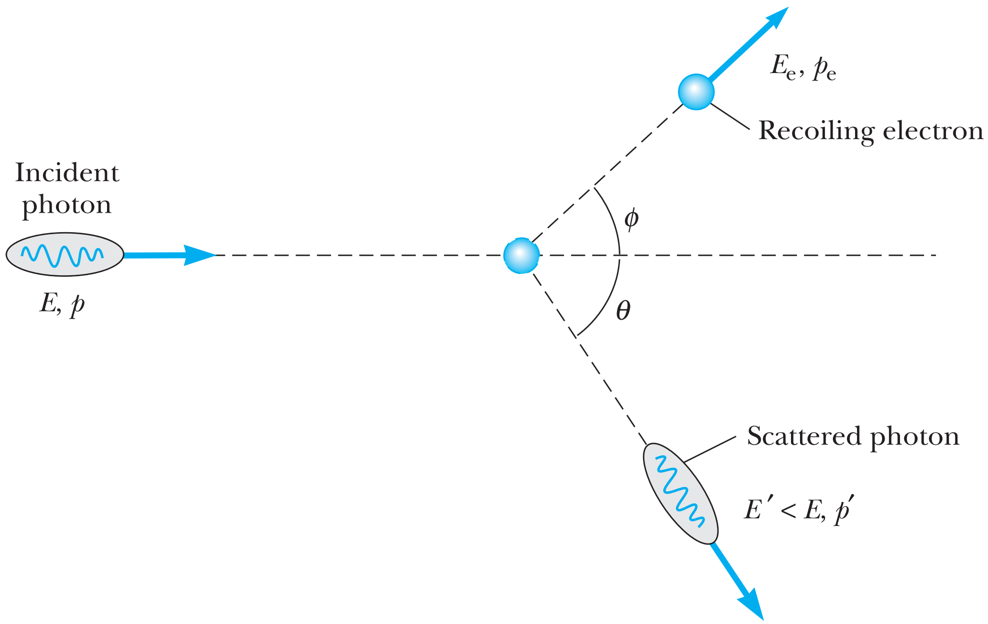


Diagram representing Compton scattering of a photon by an electron.



Conservation of energy

$$E + m_e c^2 = E' + E_e$$

Conservation of momentum

$$p = p' \cos\theta + p_e \cos\phi$$

$$p' \sin\theta = p_e \sin\phi$$

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Therefore

$$p_e^2 = (p')^2 + p^2 - 2pp' \cos\theta$$

With De Broglie relation

$$p_{\text{photon}} = \frac{E}{c} = \frac{hf}{c} = \frac{h}{\lambda}$$

We have

$$E_e = hf - hf' + m_e c^2 \qquad E_e^2 = p_e^2 c^2 + m_e^2 c^4$$

$$p_e^2 = \left(\frac{hf'}{c}\right)^2 + \left(\frac{hf}{c}\right)^2 - \frac{2h^2 ff'}{c^2}\cos\theta$$

Finally

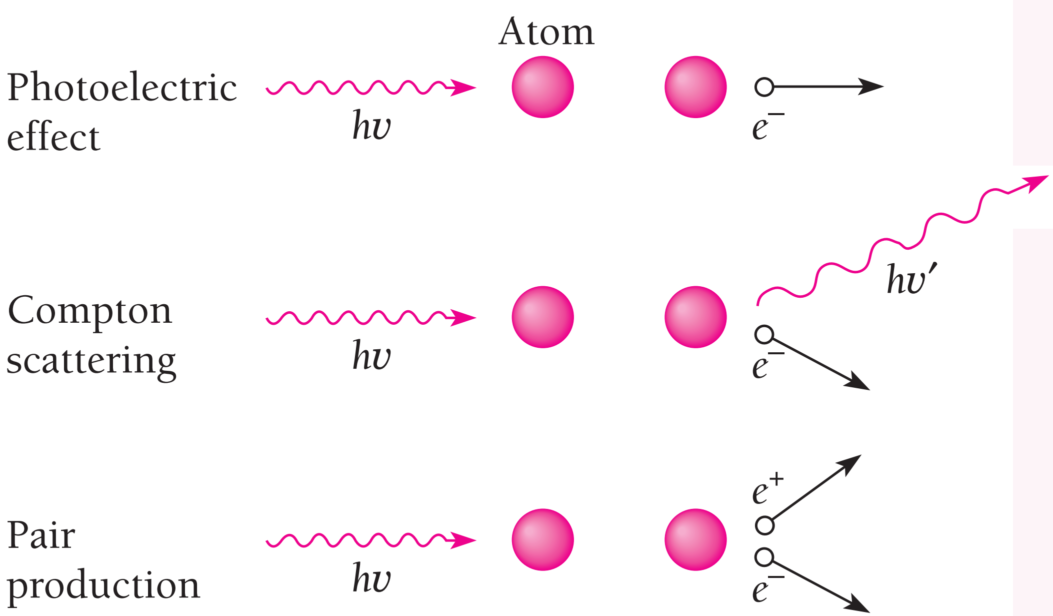
$$\lambda' - \lambda_0 = \boxed{\frac{h}{m_e c}}(1 - \cos\theta)$$

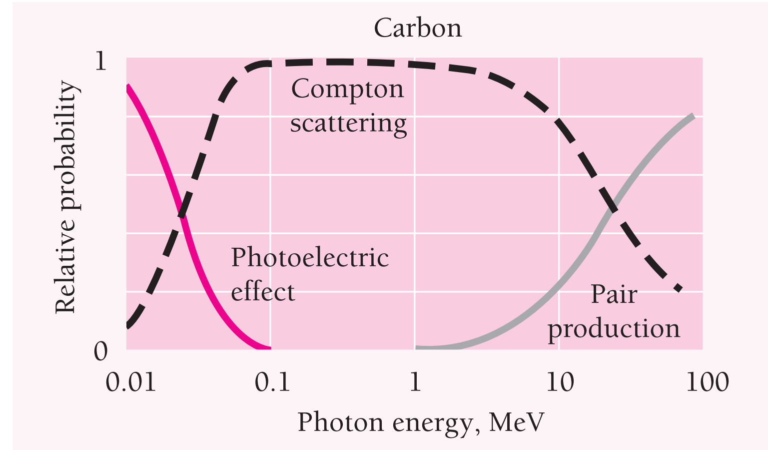
→ **Compton wavelength**

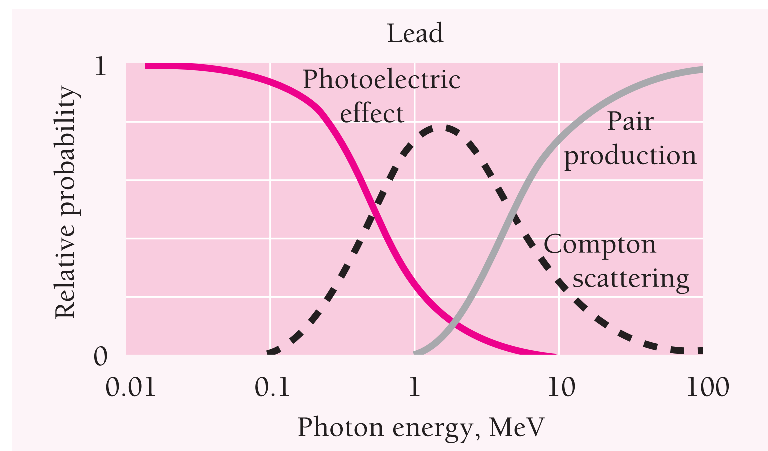
$\lambda_C = 2.426 \times 10^{-3}$ nm

6.4 Photon absorption

The three chief ways in which photons of light, x-rays, and gamma rays interact with matter







The intensity I of an x- or gamma-ray beam is equal to the rate at which it transports energy per unit cross-sectional area of the beam.

$$-\frac{dI}{I} = \mu\, dx$$

Radiation intensity I

$$I = I_0 e^{-\mu x}$$

Absorber thickness

$$x = \frac{\ln (I_0/I)}{\mu}$$