L6

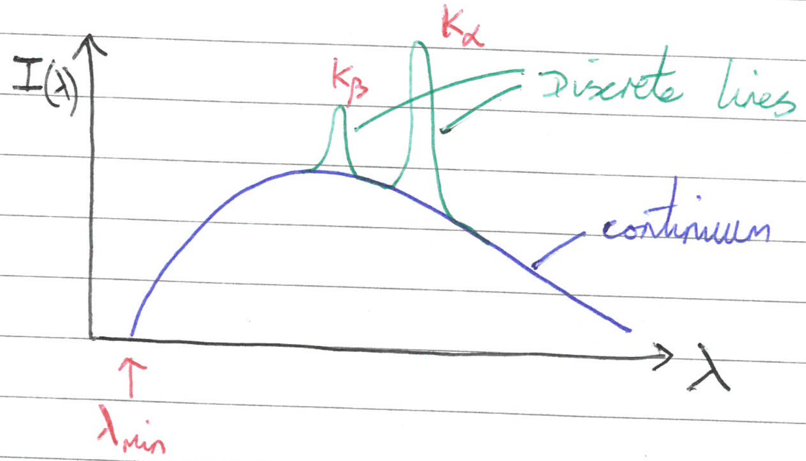
X-ray Spectra

1

- What spectrum do we get from a typical X-ray tube?

Source: metal bombarded by high energy electrons → causes e^- energy level changes in deep electron shells in the metal
→ characteristic of the anode (metal) material

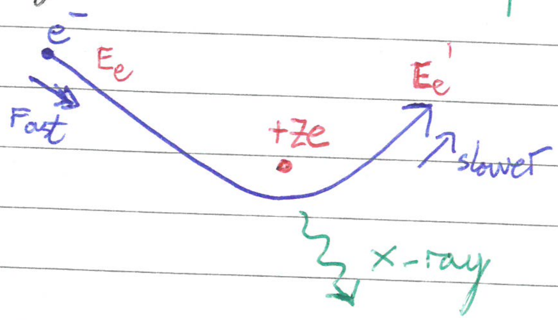
X-Ray Spectra



The continuum background is due to 'Bremsstrahlung'

Bremsstrahlung

'Braking Radiation' - independent of anode material



→ Kinetic energy lost, radiated as x-ray

$$E_{x\text{-ray}} = E_e - E_e' = \frac{hc}{\lambda}$$

- The minimum wavelength λ_{min} means maximum X-ray energy
  - ↳ ie when $E_e' = 0$ (electron stops completely)

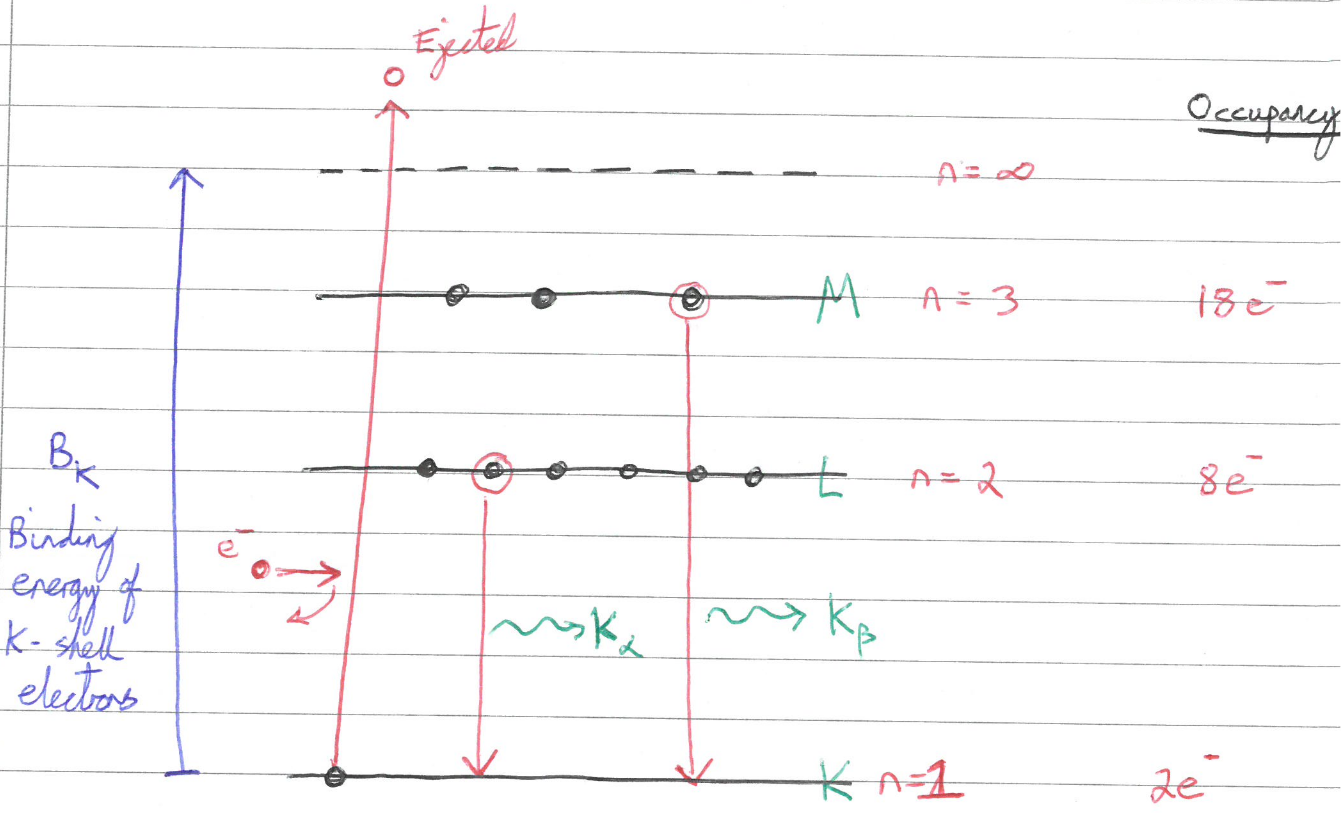
$$\frac{hc}{\lambda_{min}} = E_e = eV$$

↑ accelerating voltage

- The discrete lines are due to inner-shell electron transitions
  → characteristic of anode material

K alpha/beta in Cu and Mo

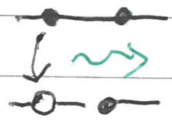
Stupid jargon! K just means $n=1$ energy level, L is $n=2$...



- If eV energy is bigger than binding energy B_K, K-shell electrons can be ejected ('collisional ionisation')

↳ Now there is a vacancy in K shell...

↳ An electron from a higher energy outer shell will fall down into it, emitting energy



K_α : $L \rightarrow K$ $(n=2 \Rightarrow n=1)$
K_β : $M \rightarrow K$ (less likely, so weaker line)

and

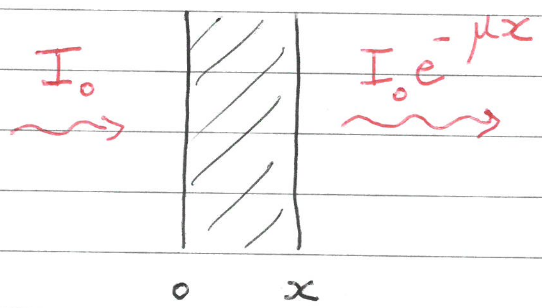
L_α : $M \rightarrow L$
L_β : $N \rightarrow L$ (need a big atom to actually have an N shell)

→ K_α etc only occur if bombardment energy is above B_K

Mo X-Ray Spectra

- X-ray absorption

  ∘ Intensity falls exponentially trough a material

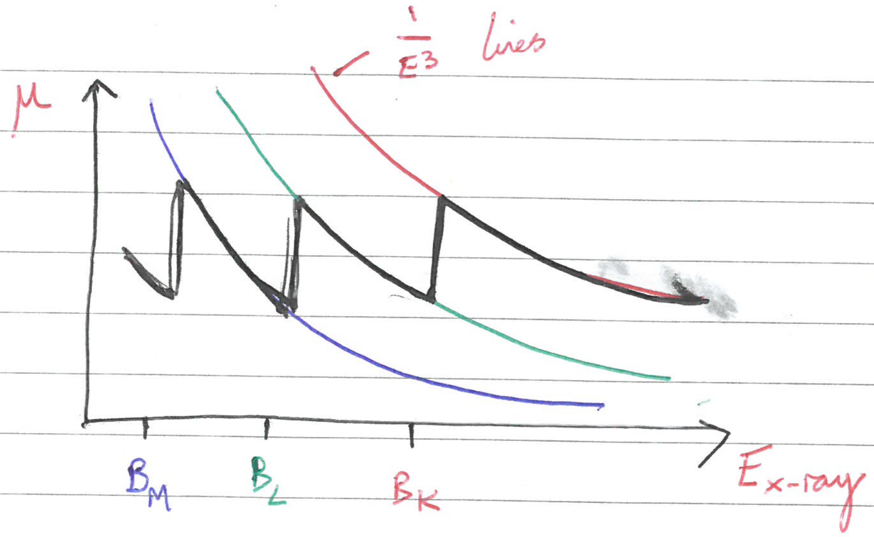


μ : material- and energy-dependent absorption coefficient

  • Absorption higher at lower energies

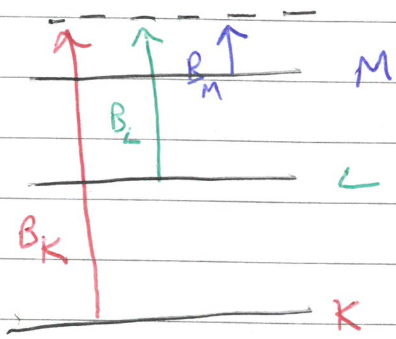
$$\mu \propto \frac{1}{E_{x\text{-ray}}^3}$$ (note: we are back to photoelectric effect!)

  ∘ Absorption drops when $E_{x\text{-ray}}$ falls below the binding energy of a given shell:



Add up μ from each shell for total

(remember:)



Absorption Edges

- Measuring these edges lets you determine what atoms something is made of, and their electron energy levels ('X-ray absorption spectroscopy')

- Moseley's Law

$$f_{K_\alpha} = (2.48 \times 10^{15}\ Hz)(Z-1)^2$$

Empirical law, lets you identify elements

Moseley's Law

→ Reinforced idea of shells, number of electrons per shell limited

→ n.b. $(Z-1)$ is because there will be a 2^{nd} e^- in the $n=1$ level, which reduces effective nuclear charge by 1 - 'screening'

- Conclusions
  - X-ray tube spectra:
    - Bremsstrahlung continuum +
    - Discrete lines (eg K_α)
      ↳ Removal of deep electrons, others fall in to replace them
  - Need to give enough energy to remove a K-shell electron before K_α and K_β lines appear
  - X-rays exponentially absorbed. Absorption μ has 'edges' ⇒ ionisation energies of the shells
  - Moseley's Law - links K_α energy to Z