Quiz 2 XRD 4/5/01

A change in momentum for a charged particle is often used as a source for x-rays.

a) **Sketch** an x-ray tube showing:
   -the source and kind of charged particles,
   -the mechanism for control of momentum of the particles
   -the mechanism for change in momentum of the particles
   -and the necessary parts to achieve and control this process.

b) **Make a plot** of intensity of x-rays versus wavelength for a copper anode for 1kV, 5kV, 20kV and 40kV
   -Give a function for the short wavelength limit.
   -Give a function for the white radiation intensity.
   -Give a function for the characteristic radiation intensity.
   -Show the wavelengths of the characteristic peaks.

c) **Describe** the mechanism for formation of the 5kV curve in part b.
   -Why isn't the radiation a single wavelength?

d) **Describe** the mechanism for formation of the part of the 40kV radiation that differs from your answer to part c.

e) **-What** material could be used to filter the 40kV radiation for an XRD measurement?
   -Explain your choice of this material.
   -How does the absorption coefficient depend on Z and λ?
   -How would you decide the thickness for this filter?

Answers: Quiz 2 XRD 4/5/01

a) -Source is a filament and kind is electrons.
-control of momentum is a high voltage drop (30 to 40kV)
-Mechanism for change is a piece of metal which serves as the anode, Cu or Mo.
-To control you need cooling water and a high vacuum 10^{-7} Torr.

b) λ_{swl} = 12.4/kV where kV is the voltage drop in kV across the tube.
$I_{Bremstralung} = K\ i\ Z\ V^2$
$I_{Characteristic} = K\ i\ (V-V_K)^{1.5}$
$Cu_{K\alpha}$ radiation occurs at 1.54Å
$Cu_{K\beta}$ radiation at 1.41Å
The critical voltage to observe characteristic peaks is 9kV for Cu.

c) White radiation represents a distribution of events of variable energy. The highest energy corresponds with a direct hit on a Cu atom by the electron in the tube. This is the source of λ_{swl} = 12.4/kV. Other more probable events involve partial collision where lower energy is involved.

d) Above the critical voltage of 9kV electrons from the K shell can be removed. Filling of these orbitals by L or M orbital electrons results in quantized energy release corresponding to the difference in energy between L or M orbitals and the K orbital. These correspond to the $K\alpha$ and $K\beta$ peaks observed in the 40kV spectrum.

e) Nickel is used (Z = 28) for Cu radiation (Z = 29) since the critical energy to remove the K shell electrons matches the β peak for Cu. The absorption coefficient depends on Z^3 and l^3, so there is a fairly sharp valley in absorption coefficient versus wavelength near the $Cu_{K\alpha}$ peak at 1.54Å for a Nickel filter. To decide the thickness of the Ni filter you would use Beer's Law, $I = I_0 \exp(-\mu t)$, where t is the thickness and the value for μ for Ni at 1.54 and 1.41Å. A fixed amount of attenuation of the two peaks would be chosen according to the resolution desired in the XRD measurement, typically $I_{CuK\beta}/I_{CuK\alpha} = 0.99$ would be a good choice. So $0.99 = \exp(-t(\mu_\beta - \mu_\alpha))$ or $t = \ln(0.99)/(\mu_\alpha - \mu_\beta)$.