X-ray Lab

Intermediate Experimental Physics Lab II
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April, 2014

Setup

1) Plug in xray machine, turn on, plug in usb and connect to computer
2) Start "xray apparatus" software on computer
3) F5 (settings menu), select usb connection in general tab
4) Put Geiger counter in sensor holder after (carefully) removing black plastic cap, tighten in place
5) Put NaCl crystal in sample holder, about 10cm from collimator hole
6) Adjust rotating sensor arm to be ~10cm from sample
7) Add collimator (turn until horizontal and solid in place)
8) Close both glass doors (sometimes you have to hold one closed while starting a scan)

Starting a run

1) F5 (settings menu), set parameters in apparatus tab: U (voltage of xray tube), I (current), angle range, angle step size, time per step
2) Click Scan, should see plot on screen start to appear, which is Geiger counts vs. angle (beta)

Theory

The electron energy is given by the electron charge times the tube voltage. This is also the maximum energy of an emitted xray.

E=eU=hc/lambda

The Bragg diffraction condition relates the angle (beta) that an xray of wavelength (lambda) is scattered at:

m lambda = 2d sin(beta)

where m is a positive integer, and d is the atomic spacing distance.

Moseley's formula predicts the energy of an xray from an atom when undergoing electron transitions:

1/lambda = R(Z-1)^2 (1-1/n^2)

where R=1.097e-7 m^-1 (the Rydberg constant) and Z is the charge of the nucleus of the atom (atomic number), which is 42 for Mo (the xray tube target).
When n= 2,3 you get the K_alpha,K_beta lines in the xray spectrum, when the inner (K) electron shell is refilled from the 2nd,3rd electron shell.

Procedure

Take runs with xray tube voltage U=20,25,30,35 kV, for I=1mA, beta=2-30 degrees, 0.1 degree beta step, 1s per step, for the NaCl sample. Print the page.
If there's enough time you can also attempt a longer run with 10s per step, for some U (like 35 kV).

1) The maximum energy xray depends on U (see above), in fact lambda_min=hc/eU. Find the minimum beta (maximum xray energy) for each run and plot sin(beta) vs. hc/2eU to find the value for d for NaCl.
2) Use this calibration to determine the wavelength of the K_alpha and K_beta peaks seen in the plots. Compare the measured values to the prediction from Moseley's formula. Do the peak positions change with U?
3) Calculate also the positions of the m=2,3,(4?) locations of the K peaks in the plots. Do they follow the Bragg diffraction formula?

Take similar runs with the Al crystal sample and perform the same analysis steps.
How does the value for d compare? Do the wavelengths of the K peaks change?

Other stuff to try

- Change the current used to 0.75, or 0.5, or 0.25 mA and repeat the Al run with U=35kV. What's the effect and what stays the same? Explain.
- What happens at even smaller angles than 2 degrees?
- What happens when adding xray filters such as Zr, Cu, Mo, Ag ?
- What if you remove the collimator?
- Lastly, with the collimator out, observe the fluorescent image on the screen (remove the cover on the right side of the machine) while performing a scan. You could try x-raying something else in there - safely!!