Lecture 2.3a Unclear Points:

Can we please go over the "Tube current vs. accelerating potential" graph.

From lecture, "A 100 keV electron can create up to 3,000 ionizations". How did you arrive at that number?

An electron typically gives up about 33 eV per ion pair produced. 100 keV/33 eV = 3000

For problem set 2.1 problem 7, does rubidium 90 decay into zirconium 90 or rather into strontium 90? The decay that I found was a beta-minus decay into strontium 90. For problem 8, are there any other processes that are not listed as the frequencies for alpha-decay don't add up to 100%?

\(^{90}\text{Sr}\) then decays, emitting a beta, to form \(^{90}\text{Y}\), which then emits a beta to form \(^{90}\text{Zr}\).

The interaction of incident electrons with valence electrons.

Mainly give off heat. Not clear as to mechanism, thoug.

Even in the space charge limited region, the relationship between the tube voltage and tube current is the same, right? The only difference with the "linear region" being that increasing the filament current when in the "limited region" at constant tube voltage will not affect the tube current?

In space-charge limited region, tube current proportional to tube voltage

Why does the filament circuit have to be very stable in the linear region?

Tube current, hence tube output, highly dependent on filament current.
On pg. 31 of the lecture you say: "The important characteristic x-rays result from the LIII to K transitions. Those are the Ka1 with energy 59.3 keV and those have a much higher energy." But doesn't K-LIII transition have lower energy difference than K-M/N transitions? Or, are you referring to the total energy emitted, which also depends on how often these emissions happen (relative number)?

Greater probability of LIII-K transition.

If Tube Current is proportional to Tube voltage (in the region of 30kV<V_tube<70kV), and Tube voltage is equal to V_o*sin(theta), and additionally radiation production is proportional to tube current (slide 6), then why is the radiation produced equal to V^2*I. V_tube = V_o*sin(theta) I_tube α V_tube = V_o*sin(theta) Radiation produced α I_tube α V_tube = V_o*sin(theta) ≠ V_o*V_o*I_o

Should be radiation proportional to VI ∼ V^2.

Why are there no characteristic x-rays at the megavoltage energies?

Production of x-rays much more efficient at megavoltage energies, so fraction of spectrum consisting of characteristic x-rays much lower

I don't exactly see how accelerating the electrons in groups allows for the potential difference to be less (safer) in an X-ray tube?

X-ray tube accelerates electrons using potential difference. High potential differences in x-ray tube are unsafe, so another mechanism must be found to accelerate electrons. Linear accelerator, betatron, microtron accelerate electrons using different mechanism.

Why does the radiography operate above space charge limited region and below saturation, whereas fluoroscopy operates in saturation region? What are the differences between the X-ray beam generated in these two cases?

First, note error in slide 6-11, 13, and 14. Filament current should be 4.1-4.2 A rather than mA. Fluoroscopy in saturation region is a consequence of lower filament current, not intentional. No consequence in x-ray beam, but we require control of both filament current and tube voltage to control output of x-ray tube in radiography.

Still a little confused over the difference between filament and tube current and which one in fact controls the x-ray intensity. How does the filament current compare to the tube current in magnitude? Does the filament current remain constant while the tube current and voltage are varied?

Filament current is adjustable. Amount of electrons boiled off from filament related to filament current. Intensity of x-rays consequence of tube current.

Are the only quantum-mechanically forbidden transitions those where delta(l) = 0? Is there a layman's explanation of why it is forbidden?
Quantum-mechanical dipole selection rules require $\Delta l = \pm 1$.

I understand that x-ray energy can be derived from the difference in energies between the initial state of an electron in the target and the final state, but how do we know what the initial state of the electron is in the first place? Couldn't an electron fill a hole from any of the upper levels?

In general, initial state is ground state. Otherwise energy would be required to move electron into excited state.

What does the "relative number" really represent when considering transitions and characteristic x-ray production? (shown in slides 31 & 33, as well as Table 2.3 of Johns and Cunningham)

“Relative number” is the strength of the dipole matrix element, or of the relative probability of the transition occurring.

You mention on slide 22 that the tube voltage is given by $V_0 \sin \theta$. I thought that this voltage was rectified to be nearly constant, i.e. direct current. Can you explain?

Voltage only becomes constant with multiple (typically 3) phase circuit.

Why are electron transitions forbidden for electron states with the same l quantum number?

Quantum-mechanical dipole selection rules require $\Delta l = \pm 1$.

On the diagram of the x-ray generator, it looks like there is one circuit if you consider the electrons that are boiled off as a current. However, you said that there are two circuits: the filament circuit and the tube circuit. Can you show us on the diagram which is which to help us visualize this?

Separate circuit for filament and tube. Draw diagram. See J&C Fig 2-2.

During the interaction of accelerated electrons with the core electrons, it is said that: "at mega voltage energies, virtually none of the energy comes from the characteristic x-rays." Please explain.

At megavoltage energies likelihood of radiative interactions leading to Bremsstrahlung is much greater.