Lecture 2.1 Unclear Points:

In lecture 1.3, when we have a carbon-12 and want to eject a nucleon, you supply $E > (\text{binding } E \text{ per nucleon})$ and you're able to knock out a nucleon from the C-12 nucleus. When you have a deuterium (1p+1n), it seems there is only one "bond" between the proton and the neutron. Then what is the difference in the consequence between supplying $E=2.222\text{MeV}$, which is the total binding energy, and $E=1.111\text{MeV}$, which is the binding energy per nucleon?

Acc to Evans (p 296), the photodisintegration reaction $H^2(\gamma, n)H^1$ requires 2.22 MeV.

The average binding energy per nucleon is not quite the energy required to remove a nucleon from the nucleus. Evans (pp 302-303) defines a quantity, the neutron separation energy, as the energy required to remove one neutron from the nucleus $(Z,N)$ as follows:

$$S_n(Z,N) = B(Z,N) - B(Z,N-1)$$

In a similar manner, the proton separation energy is the energy required to remove one proton from the nucleus $(Z,N)$ and is given by

$$S_p(Z,N) = B(Z,N) - B(Z-1,N)$$

I'm having difficulty understanding diagrams of decay schemes and complex decay schemes.

pg. 5: "uranium 238, radium 226, radon 222 etc., are all radioactive because they have a long half-life... or they are part of this chain." Does this mean that long half-life is a cause of radioactive decay?

The first radionuclide in a chain must have a long half-life for the series to appear in nature. Instability of the nucleus is the cause of the radioactive decay.

The transcript is cut off--I would really appreciate it if you could fix the transcript before class.

Fixed through lecture 2.3b

In alpha decay, since an alpha particle is 2p+2n, where do the excess electrons (2e-) go?

Essentially what happens in α-decay is that the α-particle knocks electrons loose from one or more nearby atoms, then picks up two of the loose electrons to form a neutral helium atom. Meanwhile, the other surrounding atoms (including the "dianion" parent atom -- the scare quotes are deliberate) very quickly reshuffle their electrons in order to have the most energetically stable configuration. This reshuffling energy, by the way, shows up as heat; strong α-emitters like radium are typically a little warmer than their surroundings, and radioactive decay is a prime source of the earth's internal heat.

pg. 28: why is beta useful for treating the surface, if it travels longer with a lot less dense ionization? It seems like alpha particles delivering big dose to the proximity of the source will do a better job treating the tumor close to the implanted source... Also, since you say that "[the beta is] going to have a more
tortuous path over a greater path length than that of an alpha particle", it doesn't seem to line up with the fact that they will deliver a very high dose right at the surface, which would seem like a very short path length and more dense ionization. Could you clarify this issue?

Alphas do not penetrate sufficiently deep to treat surface.

What exactly does the "encapsulation" of a radiation source do?

Filter out alphas, betas, and low energy gammas.

Pg. 31: where did you pull out the fact that electrons of 1.71MeV max energy will travel app. 8mm in water?

Electrons lose approximately 2 MeV/cm in water.

Could you explain more in detail how the imaging process with Technetium works, in relation to its half-life and the energy given off?

140 keV gammas penetrate sufficiently to reach image receptor. Short half-life means rapid decay.

Pg. 23: mass of P nucleus.. I assume that the number 31.98403 is the mass of the neutral atom? Where do you get this number?

Not sure. P32 atom has mass of 30.97376. Number used comes from Johns & Cunningham

In electron capture, is the energy from the process “p+ + e- -> n + neutrino + E” ALL taken up by the neutrino? As in, is this energy ever put off in a usable form—ex. Gamma ray?

When is fluorescent yield used?

So whenever an atom’s excited nucleus emits energy to fall to its ground state, do we say the atom undergoes isomeric transition?

The excited nucleus must have a sufficiently long half-life to be considered a metastable state.

Should we have each of the decay schemes presented in the lecture as walking around knowledge, aka be comfortable enough with them to refer to energy differences, particles emitted, type of decay at any time?

You will eventually become familiar with these decay schemes. Don’t worry about spending time to memorize them.

The distinction between allowed and prohibited transitions was not quite clear to me from the text.
Selection rules based on changes in angular momentum determine which transitions are allowed and which are forbidden.

I don’t understand internal conversion very well.

The chemist in me wonders what happens to the extra electrons in an alpha decay. Take for instance the alpha decay discussed in the lecture: Ra-226 -> Rn-222 + He-4. The alpha particle is just a helium nucleus, and has an electric charge of +2. The radium is neutral. Due to charge conservation I would assume that the Radon carries an electric charge of -2. However, radon is a noble gas, so it is probably not particularly happy with a couple of extra electrons floating around its valence shell. What happens to these electrons?

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In the diagram for the positron decay involving sodium, Emax = 0.54MeV is the transition energy, is this the energy imparted to the neutrino?

Some energy imparted to neutrino, some imparted to positron. Average energy imparted to positron is approximately 1/3 transition energy.

Saying that neutrinos have no mass is somewhat misleading. Negligible mass yes but the sum of the three neutrino mass flavors is ~0.32 eV.

The Standard Model assumes neutrinos are massless but recent (last 20 yr) indicates neutrinos must have mass. Value of 0.32 eV is recent (2010).

In Alpha decay example, in calculating dose rate, we count the summation of the each energy state multiplying by their branching ratio. For the same example of dose rate calculation for Beta decay, why we do not use these branching ratio? In page 32 we say the mean beta energy is 0.33*1.71, but why not 1.71*0.33*95+0.51*0.33*5%?

32P, the example used on that slide is a pure beta emitter. The 95%-5% branching ratio referred to the decay of 137Cs.

I believe there is a mistake in slide 22 of transcribed notes. P32 is mentioned as having 17 protons and 17 neutrons. Shouldn't it be 15 protons and 17 neutrons?
Correct. The change has been made.

For a complex decay scheme, how can we determine which type of radioactive decay can be neglected?

If the branching ratio is very low, we can neglect the decay path.

I'm a little confused as to the idea of mass defect as it relates to the threshold energy for positron decay. I understand that the emitted positron will annihilate with an electron and the energies of the positron and electron must equal the energies of the resultant gamma rays, but I don't follow why 1.022 MeV is needed for the initial decay to happen.

Compare to beta-minus decay. Mass of daughter plus mass of electron equal mass of parent. In positron decay, mass of daughter plus mass of positron is 1.022 MeV greater than mass of parent, so we need to find additional 1.022 MeV of energy for mass-energy balance.

Confused on how to predict how a nucleus will decay using the odd-odd or even-even and the stability curve, and taking account whether there are "stable isobars" nearby. I am looking at slide 39... "Now there are cases where we have an odd-odd nucleus with stable isobars on either side. These can decay via both routes..."... I have to go back and review the n/p ratio... their is a "preference" for even numbers for each neutrons and protons, and a n/p of 1?

Odd-odd, even-even, and line of stability are just rules of thumb. There are always exceptions. Most common ones, you'll eventually have memorized; others you can always look up.

Beta decay: "we could almost look at decay as a neutron being converted into a proton plus an electron" and an antineutrino... Hm... Why can't we Actually just look at it that way. In what sense is that NOT what it is. Same question for the other metaphors

Simplistic explanation doesn’t quite explain why half-lives are different, energy levels are different, etc., for different nuclei.

Electron Capture - I'm lost as to how/why this is a competing process with positron emission. I understand the 1.02 MeV threshold (must have the rest mass of the pair). I am flummoxed as to the relationship to electron capture.. I'm on slide 40 here... comes up again on slide 42 where you show the branching ratio for these two... I'm not following picture of what is going on and why these relate

In both cases a proton converts to a neutron. In electron capture, this is done by capturing a neutron, in positron emission, this is done by ejecting a positron.

Internal Conversion competes with Gamma emission (slide 44). I understand the nucleus is in an exited state and dumps energy one of these two ways. so there would be a branching ratio but we are not able to measure this one? You say in the lecture "the exited nucleus can also impart energy to an inner shell electron". Sounds like magic. Just a glimpse on how that happens? What goes on there?

Evans (The Atomic Nucleus) explains it as an interaction between the bound inner-shell electron and the nuclear multipole field.
Electron capture vs internal conversion: are they essentially the same with the exception of energy levels?

No, in electron capture the electron is absorbed by the nucleus, whereas in internal conversion, the electron is ejected from the nucleus.

Is the difference between beta minus particles and electrons the same as the difference between gamma and xrays, i.e. originating from nucleus vs. originating from atom? Is beta plus decay the same as positron emission?

No, beta minus particles and electrons are the same thing regardless of source. Beta plus decay and positron emission are the same.

Can you please elaborate on what is a branching ratio for radionuclides that decay via both electron capture and positron emission?

Branching ratio is fraction of nuclei decaying via a specified path.

What are the differences and similarities between mass defect as it relates to binding energy and radioactivity?

Mass defect is a measure of binding energy. With knowledge of mass defects, we can calculate energies of radioactive transitions.

Is there such a thing as "medium mass nuclei"?

If it’s not heavy, and if it’s not light, it’s medium.

When a nucleus absorbs a photon with energy greater than the binding energy, what happens to the photon’s excess energy?

Goes into kinetic energy of ejected particle.