Big Picture Podcast – Episode 08

The Atomic Nucleus and Radioactivity, Chapter 5B

Tracy: Welcome to the Big Picture podcast. We're now in the chapter on the atomic nucleus and we're going to do the review.

John: Do the review.

John: Hey. But I thought maybe we should make a couple of comments about the previous episode with Rocky Flats. Would you think of that?

Tracy: That was really interesting. You know, I was thinking about it later as I was describing it to some friends, and I was realizing that if you hadn't told me that it was a contaminated place

John: You mean in the area?

Tracy: Yeah. I don't know that I would have known that it looked, you know,

John: Like

Tracy: Like a

John: Regular

Tracy: Regular

John: Fields.

Tracy: Field, right?

John: Right.

Tracy: Yeah. Grasslands. There were no birds. There were

John: The

Tracy: Rabbits,

John: Crickets.

Tracy: Crickets. Two

John: Two

Tracy: Headed

John: Headed rabbits.

Tracy: Rabbits. The two headed rabbits. That was not real.

John: But the thing is, one might expect if there's plutonium in the ground, that everything is just nuked and just just

Tracy: Yeah.

John: Dead, right.

Tracy: Yeah, I actually expected it to be more of a dust field, more barren, more just compact soil. You know, really not living. So

John: I think that's

Tracy: That's

John: A good

Tracy: Good.

John: Segway into the first part of this nuclear chapter where we talk about how it is that radioactivity is a natural thing, it's been here on Earth since day one. We're exposed to radiation on a on a daily and nightly basis.

Tracy: Like all of us all the time.

John: Well, there's radiation coming from the. From space. There's radiation coming from the ground. There's radiation. The food we eat. There's radiation in the air we breathe. And that's not radiation created by humans. That's radiation. That's what we call in the natural background.

Tracy: Well, OK. So can we actually hone in and talk about what is radiation?

John: All right. So it's a form of energy, ESI.

Tracy: When you say energy, are you talking about something physical that can hit you?

John: Yeah, they're actually particles like tiny little bullets that are coming at you.

Tracy: Okay, so radioactivity is already in our environment. You said. And so where's that radioactivity coming from?

John: The ground, the sky, from the food we eat, it occurs naturally.

Tracy: What's the source of it?

John: The source, it's the atomic nucleus. And that's what we're going to dig into the atomic nucleus and how it's structured and its behavior and how sometimes that behavior can result in the release of this thing we call radioactivity.

Tracy: So is there more than one type of radioactivity?

John: We have identified three types of radioactivity and we call them alpha, beta and gamma radioactivity.

Tracy: Alpha, beta

John: And

Tracy: And

John: Gamma

Tracy: Gamma.

John: And the Greek letters ABC Alpha Radiation consists of what we call alpha particles and guess what an alpha particle is?

Tracy: Well, I asked if I could get it at the store and one of our other conversations, but an alpha particle has to

John: Actually,

Tracy: Do

John: You

Tracy: To

John: Can't get

Tracy: Get

John: It

Tracy: It.

John: At the store if you get some helium, helium gas or in the store helium balloon.

Tracy: A helium protocol is two protons and two electrons.

John: And two neutrons. And

Tracy: And

John: So then

Tracy: Two neutrons

John: In the nucleus,

Tracy: Nucleus.

John: You've got two protons and two neutrons recall from a previous chapter. And when you just have the nucleus of a helium atom, forget the electrons, just the nucleus, two protons, neutrons. You've got what we call an alpha particle.

Tracy: So.

John: Now take that alpha particle and get it flying from point A to point B really fast. Then you call that alpha radiation. It's like a bullet. If if you're holding in your hand, it's not going to hurt you. But if you shoot it out at hundreds of miles per hour, that bullet can very well hurt you. In

Tracy: Well,

John: Fact.

Tracy: Anything that you shoot at 100 miles

John: Yes,

Tracy: An hour can her

John: Exactly.

Tracy: Exactly,

John: In the

Tracy: Just

John: End,

Tracy: Sandy.

John: Including the nucleus of a helium atom.

Tracy: Ok.

John: That's

Tracy: That's

John: What

Tracy: What.

John: An alpha particle is.

Tracy: So it can be benign or it can be harmful.

John: If it's going really fast, it can hurt it.

Tracy: Okay.

John: If

Tracy: If it's

John: It's just

Tracy: Just.

John: Sitting there, it's not going to hurt. The faster it goes, the greater its kinetic energy.

Tracy: Ok.

John: So,

Tracy: So.

John: Chris Time, what's alpha radiation?

Tracy: It's a moving helium nucleus.

John: It's a fast moving helium nucleus.

Tracy: A fast moving helium nucleus.

John: Yeah, it's

Tracy: Ok.

John: Actually been shot out of a larger nucleus. We'll talk about

Tracy: But does

John: That

Tracy: This

John: Have

Tracy: Happen

John: Been.

Tracy: Naturally?

John: Naturally. Yes.

Tracy: Yes. Okay.

John: Absolutely.

Tracy: Okay. All right.

John: And

Tracy: And

John: Then

Tracy: Then.

John: Beta radiation is an electron that's moving really fast like a bullet.

Tracy: Ok, wait a minute. But I thought you said radiation came just from the nucleus and electrons

John: It does

Tracy: Aren't in

John: In the

Tracy: The

John: News,

Tracy: Nucleus.

John: But they can be generated within the nucleus.

Tracy: Say

John: So

Tracy: More.

John: An electron can be shot out of the atomic nucleus and you're actually pointing up. But wait a second. There are no electrons in the atomic nucleus. Now we'll be discussing how it is a neutron can transform into a proton. And as it does so, it spits out an electron. We'll

Tracy: We'll get

John: Get we'll

Tracy: We'll

John: Get

Tracy: Get

John: To

Tracy: To

John: That.

Tracy: That, okay. That sounds fascinating.

John: But

Tracy: But.

John: The electron being shot out from the atomic nucleus like a bullet is what we call beta radiation. If you're receiving beta radiation, you've got a bunch of electrons being shot at you. Ouch.

Tracy: Okay. Mm hmm.

John: Yeah.

Tracy: Yeah.

John: So alpha radiation and beta radiation are both forms of these subatomic particles flying at very high speeds. Right.

Tracy: Ok.

John: Ok. They're like

Tracy: Is

John: Little,

Tracy: There another one

John: Little

Tracy: Little

John: Bullets

Tracy: Bullet

John: At the

Tracy: That

John: Third.

Tracy: Set off a beta?

John: The third type is the gamma radiation.

Tracy: Aviation.

John: Now, gamma is a little bit different. Gamma is a form of light electromagnetic radiation. And, you know, visible light has like red, orange, yellow, green, blue, indigo, violet

Tracy: I that though

John: That we

Tracy: His.

John: Can see. And the higher the frequency like violet, the higher the energy you get to ultraviolet. That's even more energy than beyond ultraviolet. You've got x rays. Gamma is beyond x ray. Gamma radiation is ultra energetic. Gamma is the most destructive of the more.

Tracy: I'm just wondering, is there a point where that energy becomes dangerous and a point below which the energy is dangerous is.

John: It depends. Now, if you're subjected to alpha radiation, beta radiation and gamma radiation, you might think that the gamma radiation is going to cause the most damage.

Tracy: Right. Because it can penetrate more and it has

John: Right.

Tracy: Much more energy.

John: Right through you. Yeah,

Tracy: Yeah,

John: But get

Tracy: Of course.

John: This, the gamma radiation will kill your cell. It's gone.

Tracy: Okay.

John: Your cell

Tracy: Cell

John: Gets

Tracy: Gets

John: Killed.

Tracy: Killed. That's not good.

John: Now, it's actually better than if beta radiation comes in in sort of damages your cell. It hits the DNA, the cells still alive, but the DNA gets messed up and it starts mutating in weird ways and it becomes cancerous.

Tracy: Okay.

John: Not good.

Tracy: All right. So

John: So

Tracy: That's what's

John: Isn't

Tracy: Happening

John: That interesting?

Tracy: With beta.

John: You

Tracy: Yeah.

John: Can have super high energy, but in terms of our health, it can actually be not as bad. It

Tracy: It's.

John: Depends is the answer. But what's true is that the gamma radiations have the greatest penetrating power.

Tracy: All right. I think we're off to a good start here.

John: So what if you dug a hole deep into the earth? Would it

Tracy: Get

John: Get warmer

Tracy: Warmer.

John: Or colder

Tracy: Colder.

John: The farther

Tracy: Father

John: You dug?

Tracy: Doug. I'm guessing warmer.

John: Why?

Tracy: Why? Well,

John: Well,

Tracy: Because

John: Because of

Tracy: Of

John: Radioactive.

Tracy: Radioactivity.

John: So when they discovered radioactivity, they realized that low this might well be why it's warmer. The deeper you go, you've got radioactivity going on deep in the earth and it adds up to warm things up and it gets so hot that the rock will melt and you form magma. It gets so hot that the rock is more like a plastic than than solid. Which permits but we call plate tectonics, where the continents are able to float over the mantle and move and collide into one another to really make this earth alive.

Tracy: Because of radioactivity.

John: I joke with my students like every semester. It's just too much fun. We've been looking over the periodic table and we've been talking about the atoms and how an atom has an atomic nucleus. And in the nucleus you have protons all clumped together and no one questions me on that. Because think about it, protons are all positively charged. How in the heck can you have all those protons held together in an atomic nucleus? Come on. There

Tracy: There

John: Must

Tracy: Must

John: Be

Tracy: Be

John: Something

Tracy: Something

John: Else

Tracy: Else there.

John: There. So

Tracy: So.

John: The electrical force is repulsive. When you have the same sign, right?

Tracy: Correct.

John: Correct. So

Tracy: So what

John: What is

Tracy: Is

John: It?

Tracy: It?

John: How can you have protons all next to each other in an atomic nucleus? That was a huge question. And in fact, that question made people not believe that the atomic nucleus was even possible. How can you get protons to to get next to each other like that? They repel. For goodness sake,

Tracy: Gravity.

John: Gravity. That's a good question. Maybe it's gravity that's holding them together. Maybe the electric force just doesn't apply when you get to the atomic nucleus.

Tracy: Yes, something

John: Really

Tracy: Really

John: Sticky?

Tracy: Sticky.

John: Yeah, actually, something

Tracy: Some really

John: Really

Tracy: Linguistic.

John: Sticky. Yeah. That's the one. Because the idea of the electric force doesn't apply in the atomic nucleus goes that goes against the idea of it being a universal force. You can't say it's a universal force except in the atomic nucleus. No. The idea is that the electrical force of repulsion is still at play, but there must be something else we haven't yet discovered. That's allowing it to stick together. In this was introduced, this notion of what's called the nuclear force. Now, the nuclear force would have to be really strong to hold protons together. So they called it the strong nuclear force.

Tracy: And is that like gravity?

John: No. Gravity is attractive, right? Turns

Tracy: Turns

John: Out

Tracy: Out.

John: The strong nuclear force is also attractive. Now the electrical force can be attractive or repulsive. Gravity is only attractive. The strong nuclear force likewise is only attractive. And that's just the nature of these fundamental forces. So the idea is this there is an electrical repulsion between the protons, right?

Tracy: Okay.

John: But there's also an attraction between the protons, the protons. Yeah, they repel by virtue of the electrical force, but they also attract each other by virtue of the strong nuclear force.

Tracy: And are those two very different forces or is it one force doing two different

John: Two very

Tracy: Things,

John: Different forces,

Tracy: Forces?

John: As far as we know right now here in this part of the universe, two very different forces and they're both occurring at the same time, a proton can be attracted to another proton, OK? It's attracted by virtue of what we call the strong nuclear force. And at the same time, it's repelled by the electrical force because two positive charges repel. So there's this battle between the two and who wins? Well, that's where the neutrons come in. Remember, what's a neutron?

Tracy: It is a protocol with no church in the nucleus.

John: Yeah, it's a nuclear on. So it's found in the nucleus and it has no electrical charge. But what do you think about the strong nuclear force?

Tracy: And it also be affected by the strong nuclear force.

John: Yes. Now the nuclear force is something exerted by all nuclear weapons. In two examples of nuclear arms are.

Tracy: The proton and the neutron.

John: He had both of them exert this strong nuclear force, so the neutrons are also attracted to other neutrons that the strong nuclear force protons are attracted to neutrons by the strong nuclear force and vice versa. And so the neutrons understand when you start throwing them into the nucleus, they don't contribute to a repulsive force because they don't have a charge, but they do contribute to the strong nuclear force, which is attractive. So the solution to holding a nucleus together, keeping those protons together, is to start adding neutrons as you add neutrons. You are enhancing the strong nuclear force while not doing anything to the electrical force.

Tracy: All right. So their influence can be like like glue, so they can be actually increasing that stickiness or that what's

John: Yeah,

Tracy: Holding

John: Holding an

Tracy: The

John: Excellent

Tracy: Nucleus

John: Year together.

Tracy: Together?

John: Yeah.

Tracy: Yeah.

John: Excellent.

Tracy: Excellent.

John: Ideally, for a nucleus to be stable, you want a 1 to 1 ratio of protons, neutrons. If you've got two protons, you need two neutrons, and

Tracy: There's

John: That's what.

Tracy: Zero particle.

John: There's

Tracy: They're zero.

John: Your alpha particle A.

Tracy: Which is also a helium particle.

John: Look at carbon, carbon has six protons in the most abundant isotope and stable isotope of carbon has six neutrons. So six protons, six neutrons and that's that's a one to one ratio. And when you have that one to one ratio, you have this optimal stability to your nucleus, because let's face it, if you took just two protons and tried to put them together.

Tracy: They would repel each other.

John: They

Tracy: They

John: Would

Tracy: Would

John: Repel

Tracy: Retaliate.

John: Each other and they would also be attracted to each other. Right.

Tracy: They would be very confused.

John: They would be confused. But there's a difference.

Tracy: There would be a struggle.

John: There is a difference, though, in that the strong nuclear force is very, very, very sensitive to distance.

Tracy: Ok, so meaning that if they're further apart than it's that strong nuclear force is actually

John: He

Tracy: Weaker,

John: Gets

Tracy: Gets

John: Weaker

Tracy: Weaker.

John: With distance. Now.

Tracy: And if they're closer together than it's that

John: Is

Tracy: Strong

John: Strong

Tracy: Nuclear

John: Girders.

Tracy: Force is even stronger.

John: We talked about the inverse square law where if you doubled the distance, it becomes one fourth as strong.

Tracy: Mm hmm.

John: Well, with the strong nuclear force, it's not one over deed of the two Lee de Squared, it's one over deed of the sixth. That is, if you double the distance, it becomes two times, two times two times two times two times two sixty four. It becomes one sixty fourth as strong the strong nuclear force. And believe me, this is key is very sensitive to the

Tracy: Distance.

John: Distance, whereas the electrical force is subject to one over D squared. Inverse square law. Yet sensitive to distance too, but nothing like the strong nuclear force, which is one over deed of the six.

Tracy: So it's six times more sensitive.

John: It's exponential,

Tracy: Exponentially

John: Exponentially more

Tracy: Sensitive.

John: Sensitive to distance.

Tracy: It's OK.

John: Right. So you put two protons together, the protons are going to be vibrating, right? The moment they vibrate and they're a little bit away from each other. Back up. The strong nuclear force dies out. The electrical force winds, those two protons, which they shoot off in opposite directions instantly. However, if you throw in two neutrons, the neutrons are going to be adding.

Tracy: Strong nuclear force.

John: Yeah, and repeatedly so because you're going to have a strong nuclear force between those two neutrons, between the two protons, between one neutron and one proton and one proton and one neutron atom all up, and it helps to bind that nucleus together. So what would happen if you just had a bunch of neutrons with a bunch of neutrons stick together all by themselves? You would think because there's

Tracy: Do

John: No

Tracy: We

John: Electrical

Tracy: Like.

John: Force of repulsion.

Tracy: And it's just the strong nuclear force getting stronger and stronger

John: They are

Tracy: With

John: Pulling

Tracy: Each

John: It together.

Tracy: Neutron,

John: That's

Tracy: Right?

John: Right. Except there's one thing we haven't talked about.

Tracy: What's up?

John: Just as protons need to have neutrons around them.

Tracy: Neutrons need to have protons around

John: They

Tracy: Them.

John: Do. And if

Tracy: If.

John: You have a neutron all by its lonesome without any proton around it, it gets unstable. It's kind of crazy and that neutrons going to want to have a proton around it so badly that. It turns into a proton itself. It becomes a proton in the process, spits out an electron.

Tracy: So the new neutron becomes so unstable if there's no protons around it and it becomes a proton

John: You

Tracy: And spits

John: Get

Tracy: Out

John: Searched

Tracy: An

John: Electron,

Tracy: Electron.

John: Yeah.

Tracy: Ok. So neutrons decay.

John: Something

Tracy: So their

John: That

Tracy: Natural

John: Just

Tracy: State.

John: Kind of downhill.

Tracy: Yes.

John: Guess which way is

Tracy: Okay.

John: More with which has more mass? A neutron or a proton?

Tracy: Well, from what you just said, a neutron.

John: Wow. That's how you got it. Excellent, excellent. Not that much, but enough. So you see what's happening there is that electron is getting spit out. Guess what? You might call that electron flying really fast.

Tracy: That was the beta.

John: And that's

Tracy: That's

John: It. That's exactly

Tracy: The beta radiation

John: Where

Tracy: Or

John: Better.

Tracy: We detected as beta radiation.

John: That and that's exactly where beta radiation comes from. Whenever you've got beta radiation, it's the result of a neutron somewhere in some nucleus transforming into a proton.

Tracy: Cool.

John: Well, here's the deal. When you start making a nucleus bigger and bigger, that one to one ratio doesn't work so well anymore. Here's the thing. As you get a nucleus that's larger and larger, distance becomes a factor. Take a really large nucleus. Go ahead. Anyone?

Tracy: Uranium.

John: Uranium.

Tracy: Uranium.

John: Ok. Uranium is a really big nucleus. It's so big that neutrons on one side of the nucleus don't really feel the strong nuclear force so well from the neutrons on the other side of the nucleus. Same thing with protons. So a proton on one side of the nucleus doesn't really feel much of a nuclear attraction to a proton on the opposite side of the nucleus. Remember, the strong nuclear force is sensitive to distance, and that distance can be the diameter of a nucleus, which ain't much. But for a large nucleus like uranium, it's enough so that the strong nuclear force is weakening out. So how could you possibly solve that problem?

Tracy: Add more glue.

John: Add more glue, which comes in the form of

Tracy: Neutrons.

John: Had more neutrons, and so that's exactly why for larger atomic nuclei you'll find it's not a one to one ratio. You'll have like a one to one point four ratio, maybe one to two ratio where you've got for every one proton you've got one point four

Tracy: New

John: Four

Tracy: Trends.

John: Neutrons. For every one proton you've got more neutrons you

Tracy: Because

John: Have

Tracy: You need more glue.

John: Cause you need more glue. Got that.

Tracy: Got that

John: All

Tracy: Right.

John: Right. Do you see the problem?

Tracy: Yes,

John: He actually

Tracy: You had.

John: Had one problem, you solved it, but you created another problem. What's this other problem?

Tracy: Well, the neutrons want to be closer to protons.

John: And as you're adding more neutrons, you're not allowing that to happen suddenly you're having neutrons that are kind of alone and there's a neutron like being alone like that.

Tracy: They just become unstable.

John: Yeah, and it will turn into a.

Tracy: It will turn into a proton,

John: Now,

Tracy: And

John: Does that

Tracy: That's

John: Help?

Tracy: Release an electron

John: In releasing

Tracy: Released.

John: Electrons. Now, does that help make the nucleus stable when a neutron is transforming into a proton?

Tracy: No, because even though it still has some some strong nuclear force, it's increasing the amount of electric force

John: Repulsion. Yeah.

Tracy: Repression.

John: Yeah. So the you're adding to the repulsive electrical force and it just makes it more unstable. So what has to happen when you have a large nucleus like that to increase the stability you need to shed protons so that large nucleus will start shedding protons in its sheds, those protons in the form of

Tracy: Alpha radiation,

John: These alpha

Tracy: Alpha

John: Particles,

Tracy: Particles, alpha particles.

John: Particles which leave the nucleus in the form of alpha radiation. So we've covered where beta radiation comes from. That's when a neutron boot spits out an electron. And now what we're looking at is where alpha radiation comes from. It's when a large nucleus is trying to shed protons.

Tracy: Oh, I just got it. Why you can go to the grocery store and buy alpha

John: Alpha

Tracy: Particles.

John: Particles.

Tracy: Yeah.

John: Yeah. Not

Tracy: Not

John: Alpha

Tracy: Alpha

John: Radiation,

Tracy: Radiation,

John: But

Tracy: But alpha

John: Alpha particles.

Tracy: Particles. But

John: Good,

Tracy: This

John: Does alpha

Tracy: Alpha

John: Particles

Tracy: Protocols have

John: Have electrons

Tracy: Electrons

John: With

Tracy: With

John: Them?

Tracy: Them.

John: Near

Tracy: Yeah,

John: The

Tracy: The

John: Alpha

Tracy: Alpha particle

John: Particle is

Tracy: Is

John: The

Tracy: The

John: Nucleus

Tracy: Nucleus

John: Of

Tracy: Of

John: A

Tracy: A

John: Helium

Tracy: Helium

John: Atom.

Tracy: And

John: Say.

Tracy: The helium is in the balloon. In the birthday balloon.

John: Understand that when you have radioactivity coming from an atom, you're having a change in the number of protons and neutrons within the nucleus. So with beta radiation, you've got, what, a neutron transforming into a proton as the neutron transforms into a proton that spits out an electron.

Tracy: Left turn.

John: Yeah. So understand it spit out an electron, but one of those neutrons turned into a

Tracy: Proton.

John: Proton and it now has another fruit.

Tracy: Proton

John: And

Tracy: So

John: So what

Tracy: What

John: Happens

Tracy: Happens?

John: To the atomic man? The moon?

Tracy: Because

John: No.

Tracy: No, by one, it

John: It

Tracy: Up

John: Goes

Tracy: Goes

John: Up

Tracy: Up

John: By

Tracy: By.

John: 1. Yet you're going up by one in the periodic table. So whenever you have beta radiation, you got to understand somewhere the nucleus just went up by one in the periodic table.

Tracy: So you've

John: So

Tracy: Changed the element,

John: You've

Tracy: You've

John: Changed.

Tracy: Changed

John: The

Tracy: The

John: Element

Tracy: Element

John: In

Tracy: In

John: That

Tracy: That

John: Process

Tracy: Process

John: Is

Tracy: Is

John: Called

Tracy: Called transmutation.

John: Transmutation. Yeah. So how about when a large nucleus emits an alpha particle?

Tracy: All right. Well, an alpha particle is two protons and two neutrons. So you're losing two protons and so it will have to go down by two.

John: Yeah, and key here is that we define an atom by the number of protons it has. So if it's losing two protons, you're going down in the periodic table by two positions. Again, you have trends,

Tracy: Transmutation.

John: Mutation. Yeah. So if you have a radioactive element such as uranium 238, you'll find it will turn into a thorium as it loses an alpha particle. But then thorium is a beta emitter, so it turns in to protect Ternium, protect Indian, loses an electron, which means it's gaining a proton. So protecting him goes back up to uranium, but not uranium 238 uranium to 34. A series of transmutation is the uranium to 34, then emits an alpha particle and it turns into thorium to 30. It's a sequence of decays. And after the end of that sequence, what has happened to the uranium atom? It's turned into thorium than it's turned into protected him into uranium, back to thorium than to radium. Then to raid on that polonium. It's cascade down leading all the way to la la.

Tracy: Looks

John: Looks

Tracy: Like

John: Like

Tracy: Led,

John: Led led

Tracy: Led. This is a great

John: Sherry.

Tracy: Chart here about how Uranium 238 decays to lead to to

John: 2

Tracy: Us

John: 0 6

Tracy: To a

John: 6.

Tracy: Six

John: Yeah.

Tracy: Year.

John: And there's a beautiful worksheet on this that I encourage you all to work on. See how this is, how this works and that's how they'll do some dating of rocks, though you'll know that all the led to 0 6. That's within that rock that used to those used to be uranium atoms. Those

Tracy: This

John: Used

Tracy: Used

John: To

Tracy: To

John: Be

Tracy: Be

John: Uranium

Tracy: Uranium

John: 238

Tracy: 238

John: Atoms.

Tracy: Atom.

John: And so how much led to 0 6 you have in there tells you how long that rock has been sitting there. In the next section, we talk about half life. Turns out the shorter the half life, the greater the radioactivity of the element.

Tracy: Well, half life is how long it takes for a certain sample. And I guess you could say one kilogram of a sample to decay into another particle or element to.

John: When we say decay, we mean it's like falling apart. It's no longer what it was.

Tracy: As well, it's what you were just talking about, trans mutating into another

John: Critical

Tracy: Protocol.

John: Note do

Tracy: You

John: Note

Tracy: Know, when

John: On

Tracy: You

John: Uranium

Tracy: Read.

John: 238 transmute it's no longer uranium 238. Now, if you had a kilogram of uranium 238, you know, is it all going to disappear at once? How fast is it going to do this? That's the question. How long will it take for that transmutation to happen? If your isotope is really radioactive, it's going to happen like that. If it's not very radioactive, it's going to take a long time. Half lives is defined as the amount of time it takes for you to get to half of what you once had. So if you start with one kilogram of let's pick radium to 26 after one thousand six hundred twenty years, you get yourself not one kilogram, but a half a kilogram. Radium 2 2 6 has a half life of 1620 years. And after that time, you're going to go from one kilogram of radium, two to six to a half a kilogram of radium, two to six.

Tracy: Plus, a half a kilogram is something

John: Yes.

Tracy: Else,

John: Yeah.

Tracy: Yeah.

John: Plus

Tracy: Plus the.

John: A half a kilogram was something else, it just didn't disappear, vanished from the universe. It's still there, but it's no longer radium 2 to 6. And then after another sixteen hundred and twenty years, you're going to have half of that and so forth and so forth. You just get less and less and less. Now, if radium 2 to 6 had a half life of 5 seconds after 5 seconds, you go from one kilogram to half a kilogram.

Tracy: They would be releasing a lot of energy.

John: Yeah, and that's to say you've got alpha particles shooting out like crazy beta particles shooting out like crazy gamma rays shooting out like crazy. You don't want that substance in the palm of your hand. It's very radioactive. If you have a short half life, that means it's look like maybe blow it up like a hand grenade. It's hard to use that analogy, but that's really what it's like. Particles just shooting off in all directions. Uranium 238, interestingly, has a half life of about four billion years.

Tracy: Put our planet's only four and a half billion years old. Yeah. So half of it's already gone.

John: Yeah.

Tracy: Yeah.

John: All

Tracy: Okay.

John: Right. And we still have a lot of it there. The original stuff there. It takes its time. So really, if you have a substance and you don't want it to cause you much harm, you want a really long half life. So that's how it is. Holding a gram of uranium. 238 is much safer than holding in the palm of your hand, a gram of radium 2 to 6, which has a much shorter half life. So it's an inverse thing, right? The shorter the half life, the more radioactive it is.

Tracy: Ok, so just for comparison, then, what's the half life of carbon?

John: Carbon twelve carbon 13 or carbon 14, which isotope? Are you talking about carbon

Tracy: Carbon 14.

John: 14, so carbon 14 of the isotopes of carbon. That's the one isotope that's radioactive carbon 12. It's got a 6 6 ratio of protons, neutrons. It's not radioactive carbon 13. That's not radioactive either. It's got six protons, seven neutrons, and that's good enough. But when you get to six protons in eight neutrons, six plus eight. That's 14. That's carbon 14. You've got a situation there where you got too many in the new

Tracy: Yet too many neutrons

John: Trans.

Tracy: And start getting unstable.

John: It's

Tracy: It's

John: Sons

Tracy: A.

John: Gets unstable and so turns out it's radioactive. Carbon 14 is radioactive and it has a half life looking right here in the book, five thousand seven hundred and thirty years.

Tracy: So that's a relatively short half life compared to uranium.

John: Yeah, that's right. Carbon 14 is far more radioactive than is uranium 238.

Tracy: So and we have carbon 14 in our body.

John: We

Tracy: We.

John: Have carbon 14 in the air we breathe.

Tracy: In the food we eat.

John: Because from the air, you get the food. Now, the chain of events. It's fascinating from space, you've got radiation coming down at this rate. One

Tracy: One

John: Form

Tracy: Form

John: Of

Tracy: Of

John: Radiation.

Tracy: Red.

John: We haven't talked about. It's just a stream of neutrons. I know they have a half life and they disappear real quickly, but you can have neutrons flying through the atmosphere and

Tracy: In

John: An a

Tracy: A

John: Neutron

Tracy: New.

John: Can collide with a plain old nitrogen isotope nitrogen 14 and like with a little billiard ball physics, the neutron goes in and it kicks out a proton. And so that nitrogen atom turns into a carbon atom because it's lost a proton. And you'll see the consequence is carbon 14. That carbon 14 used to be the nitrogen in our atmosphere. So now you have this radioactive carbon in our atmosphere in carbon loves to chemically bond with oxygen and you cap carbon dioxide. Plants absorb that radioactive carbon dioxide into their plant matter. Then the cow comes along and eats that plant matter. Now the carbon 14 is in the cow. Carbon 14 created in the atmosphere by radiation from space turns into carbon dioxide, radioactive carbon dioxide because it has a carbon 14 carbon isotope in it. That radioactive carbon dioxide is absorbed by a plant via photosynthesis. Now a cow comes along and eats that plant. The Carbon 14 is now in the cow. Somebody comes along and eats the cow

Tracy: Milk.

John: Milk. Excuse me. Somebody comes along and drinks the milk from the cow. Now that radioactive carbon 14 is in you. So you see, you can't eat something. Be it animal or plant without absorbing carbon 14 into your body. It's just all over the place. That concentration isn't much, but it's all over the place. Enough to be measured. Hold a Geiger counter up to anybody and it's going to go because of the radiation coming from your body, which came from the food you eat, which came from photosynthesis, which came from the sky. It's all connected. Guess what you stopped doing after you die?

Tracy: Eating.

John: Eating, eating.

Tracy: Eating.

John: Yeah. You stop eating. And once you stop eating, you're no longer taking in carbon 14 anymore. In carbon 14 has a half life of about 5000 years. Sorry. Right here. Yeah, about five thousand seven and thirty years. If you died five thousand seven hundred thirty years ago, you're gonna have half the amount of carbon 14 in you than someone who's still alive. So hold the Geiger counter up to any living matter that's been dead for five thousand seven thirty years in the Geiger counters. Gonna read half. You flip that around. Go hold the Geiger counter to something that its readings half of what should be normal. From that you can deduce it died about five thousand seven hundred thirty years ago. And if it's been dead for much longer, it's going to have even less radioactivity coming from it. We call this carbon 14. Dating or isotopic dating? Radioactive dating.

Tracy: That's pretty cool.

John: For Carbon 14 dating, it's only good as far back to about 50000 thousand years in terms of being accurate because there are changes in the amount of carbon dioxide in the atmosphere, changes in the amount of radiation that comes down from outer space variability is like that, given uncertainty that gets just too much. After about fifty thousand years. But back to about fifty thousand years. Carbon dating is a wonderful tool for measuring the age of one's living matter. And it could be like the straw inside an adobe brick. If it's something older than fifty thousand years, you need to look to other isotopes for measuring the age. This principle is the same. You can measure how old an object is by looking at the amount of radiation that's coming from it. Now.

Tracy: And that's the principal way that things are dated, is by through looking at the radiation.

John: That's a principal way there. There are other ways. Geologist, an archaeologist do that dating. Relative dating is a good one where you just look to see which is buried deeper.

Tracy: Okay.

John: Yeah. And

Tracy: There

John: Then

Tracy: Are

John: There are other

Tracy: Other things.

John: Things that we go and Leslie Suzanne go into with our Earth science chapters. Fascinating stuff.

Tracy: Cool.

John: Very

Tracy: Very

John: Cool.

Tracy: Cool.

John: And gosh, that brings us up to the nuclear fission and fusion. And I think this would be a great place to stop for this podcast. The first half of this chapter on the atomic nucleus in the next podcast will give more attention to nuclear fission and fusion. He will even talk about thorium reactors. How about that?

Tracy: That is what I want to hear about.

John: Then let's do it. Theme Music by Zach Geoffrey. Musical Flourishes by the Silent Boys. Production Assistance from Greg Simmons and CPro Music. For show notes and more, please visit conceptualscience.com. A note of appreciation to all instructors using Conceptual Academy. Thank you for your support. And to the hardworking student, our thanks to you as well for your learning efforts, which we see as the path to making this world a better place. There's a bigger picture. That's good chemistry.

John and Tracy: Good chemistry to you