Big Picture Podcast – Episode 06

Subatomic Particles, Chapter 4C

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Tracy: Welcome to episode six of the big picture podcast.

John: This is the episode where we finish up Chapter 4 of Conceptual Chemistry.

Tracy: Quantum mechanics.

John: Eh.

Tracy: We're finally here.

John: Now don't get too excited. We're not going super deep into this. Hopefully, though, just enough to help you with the big picture.

Tracy: Any math? How much math are people going to need?

John: Remember we're conceptual. We're diggin to heavy concepts. That's for sure. But for the math, you'll just need to know, like, which is bigger, 3 or 2. You good with that?

Tracy: Okay. Where do we begin?

John: We begin by making sure we have a handle on the nature of light.

Tracy: Of light. Ready.

John: Light as it says in the title is a form of energy. I think we mentioned this before. There are two things in the universe matter in energy in the two are actually into convertible by Einstein's equation E equals M C squared. I bring this up because that is important to quantum mechanics as we shall see shortly. But when we talk about light we're on the side of that equation where it's like pure energy rather than being matter so energy manifests itself in the form of a wave. When we're talking about light what is it exactly that's waving. Turns out what's waving is electric and magnetic fields. Now I know you understand a magnet has a magnetic field around it and so I like to use that by analogy. Take a magnet and you can envision the field lines surrounding that magnet. Now quickly flip the magnet just twist in your hand and the field lines are going to follow. If you take that magnet and flip it back and forth back and forth back and forth you'll see those field lines are flipping back and forth back and forth back and forth. So by moving the magnet you can create what are essentially waves in those magnetic fields. Now when we talk about light what's moving here is typically the electrons the electrons not very massive. It has a charge around that charges in the electric field. Now as that electron vibrates back and forth guess what happens to that electric field?

Tracy: It vibrates back and forth

John: The electron is vibrating from physics we learn that when you change an electric field you necessarily generate a little magnetic field. And as that magnetic field is being generated it actually feeds back to generate the electric field the electric field and the magnetic fields are intricately entwined. They reinforce each other. And so you can't take an electron and start moving it around without creating these ripples in electric and magnetic fields surrounding that electron get that electron moving back and forth like seven billion times per second. Those ripples and electric and magnetic fields are detected by the retina of your eye. That is the very nature of light. They are ripples in electric magnetic fields. It's a form of energy. And that energy is coming in the form of a wave reaches our eye and it tickles the back of her eye. It sends a signal through her optic nerve to our brain and we go are I. So there's your quick description of electromagnetic radiation. You understand it's called electromagnetic because it involves electric and magnetic fields. It's called radiation because it radiates outward from the source of vibration say an electron. It might be an electron that's vibrating now.

We have the electromagnetic spectrum. You can have the electron moving back relatively slowly at only like hundred or thousand times per second and you generate what are called radio waves make it vibrate back and forth faster. Ten to the eighth Hertz and you have microwaves even faster you end up with infrared and four times tend to the 14th Hertz cycles per second.

John: You're there now invisible light beyond visible light you have ultraviolet then you have x rays and you have Gamma. The point is they are all the same thing. Radio is micro waves infrared light vulture light come on an x rays are all forms of the same thing that we call electromagnetic radiation. Put them all together and you have what's called the electromagnetic spectrum four point six atomic spectra in the quantum hypothesis. Now that we have a bit of understanding on the nature of light different colors are merely different frequencies of electromagnetic radiation. We can start applying this to the world of atoms and molecules let's introduce what we call the spectra scope the spectra scope what it does is it simply passes light through. That's essentially a prism. Technically it's a diffraction grating and it splits light into its component colors. It shows you rainbow of light white light turns out to be the combination of our G.B. red green and blue altogether. So you take that white light and pass it through a prism or diffraction grating and it will separate it into its color components. You'll see the rainbow of colors. Now that's what a spectral scope does. It just slits the light that you're looking at into its color components. What happened here is they started looking at elements that were being heated. They were looking at the light from that process through the spectra scope and they were finding something quite bizarre each element emitted not every frequency of light an element would emit only particular frequencies of light.

Tracy: Of light.

John: You mean like

Tracy: You mean

John: A fingerprint.

Tracy: Like a fingerprint.

John: Exactly. If you look at strontium through the spectra scope you'll see a certain pattern of lines and that will be different from if you're looking at say barium through the spectra scope. Now what we're talking about here are the atoms of particular elements. When you heat them up. Sure enough the electrons of those atoms are vibrating and they generate light. The deal is this Each element emits a particular pattern of light. The question was this Why. Because they're different

Tracy: They're

John: Elements

Tracy: Different elements they have

John: Fingerprints.

Tracy: Different fingerprints.

John: It's their identity.

Tracy: It's their identity.

John: So you can

Tracy: So

John: Look at

Tracy: You can

John: Your

Tracy: Look

John: Fingerprint

Tracy: At your fingerprint

John: And see well we're different by the patterns but why are they different like that to get to that why you're going to need to go down to the level of the DNA. Right. What's behind it. And so likewise they're looking at this atomic spectra they're saying what's behind it why is it that strontium looks like that and barium looks like this from the study of atomic spectra particularly the specter of hydrogen. The simplest of all came the idea from Niels Baur of what we call the quantum hypothesis. Now you understand people are having a hard time believing that matter is made out of these particles rather than being continuous like a putting or something. Well when you have matter made out of particles really what you're talking about is matter being quantized quantized that means it comes in discrete quantities like steps on a staircase as opposed to a ramp a ramp would be smoothing continuous way of getting upstairs. So looking at the particular nature of matter we see that it's quantized in that took some time before we really began to embrace that model of the nature of matter the ideas of atoms. So in a way you're already familiar with the idea of the quantum because we've talked about atoms and particles already down to subatomic particles even what's different here is that Miles Baugh is talking about not just matter being quantized but dermal energy itself being quantized so he proposed this within an atom you have what he called for lack of a better word at the time orbits and an electron in a higher orbit would fall down to a lower orbit.

John: And when it did so it's losing energy because you're going downhill you're getting closer to the nucleus you're an electron and you're going to a low orbit you're going downhill effectively because you're getting closer to where you want to be when you do that you're losing energy in the energy is lost in the form of light being emitted by that particular atom he was proposing the DNA behind why it is that different elements have different fingerprints. He was saying that well the electrons are going around this thing called the nucleus maybe the electrons are held to these different orbits. And so when we're looking at the fingerprint of an element we're really looking at the pattern of orbits within that atom as an electron falls from a higher orbit to a lower orbit. You might be thinking like a squirrel jumping from a higher branch to a lower branch. That's not what he was proposing at all. He was proposing that energy itself is quantized so that there's nowhere in between. It's like the steps on a staircase. Put your seat belt on that electron going from the higher to lower orbit doesn't travel from the higher to lower orbit. It flips like a light switch. It's either there or it's here and it's never in between. Just as the bizarreness of having space the vacuum of space in between different particles is the oddity of the particular nature of matter.

John: This is the oddity of the particular nature of energy itself. It's called quantum theory. Now theory means a well tested explanation of the nature of the universe and quantum theory has been confirmed over and over again just as the theory of gravity. I don't want any hesitation when you hear this idea of quantum theory that elevates its status a quantum theory is here to stay. It's something we need to work with scientists do on a daily basis and they're their considerations. It's a world view if you will. That's beyond what we normally see. But down at the world of atoms in their subatomic particles this idea that energy is quantized is everything. It dictates the behavior of those atoms. And again remember we're talking about conceptual models here. We want to be able to predict the behavior of those atoms. Quantum mechanics is the way to do that. So if you really want to know about what's going on there you need to learn more about this thing called quantum mechanics and you can bet it goes into lots of detail. They don't need to do that here to get to the gist in terms of how it is that atoms and molecules behave. So we're going to skim over a lot of it but we want to give you the higher level big picture stuff relative to quantum mechanics.

Tracy: Okay. So quantum mechanics it goes from a higher state to a lower state. And during that process there it goes from one to the other without at any point being in between the two.

John: Absolutely. So that

Tracy: So that

John: Is what

Tracy: Is what is

John: Quantized. That's the bizarreness of quantum mechanics is that there's nowhere in between. It's truly the steps you can have an electron there or an electron here

Tracy: So it's just like how I think about I might want one thing one minute when I want something else the next.

John: Yeah. It's it's a

Tracy: It's

John: Or b

Tracy: A or B.

John: There's what's in between a hint.

Tracy: There was no

John: They

Tracy: Process

John: Are

Tracy: Just happened.

John: Are alpha

Tracy: Our

John: That

Tracy: Alphabet

John: Is quantized.

Tracy: Is quantized

John: That's a fun thing

Tracy: Funding

John: To do to think about what what's quantized money is quantized the smallest unit is a penny at least in U.S. currency lots of things are quantized including energy so when an electron jumps from a higher state higher energy state to a lower energy state it emits light when it's absorbing light that energy of the light lifts the electron from a lower state to a higher state higher

Tracy: In the

John: State

Tracy: Higher states

John: Further

Tracy: Are further

John: Away from

Tracy: Away

John: The nucleus.

Tracy: From the nucleus

John: Yeah. Think of it in terms of gravity you know the higher you go up the ladder the more potential energy you have the more it's going to hurt. If you were to jump off that ladder likewise for the electron it's negative. The nucleus is positive. There's an attraction between the two. So as you pull the electron away from the nucleus that takes energy to actually pull the electron away from the nucleus. And conversely when the electron falls down toward the nucleus that's the opposite. It's like falling down the ladder. Energy is released the energy here is a form of kinetic energy. To be sure but it's electromagnetic radiation which happens to be a form of kinetic energy if y. So the electron shifts. I don't to say falls shifts from a higher state to lower state bam light is emitted. And how far of a jump that is determines the frequency of the light that is emitted if it's falling pretty darn far it's going to be a higher frequency if it's not so high of a jump. It's going to be at a lower frequency. So that's how it is the spectra of different elements the patterns the fingerprints that you're seeing there are indicative of these quantum states within the atom if this isn't trippy enough it it's time to go over the edge. You're probably thinking of an electron as a tiny particle.

Tracy: Protocol.

John: Yes a tiny

Tracy: A

John: Protocol.

Tracy: Tiny protocol.

John: Ok. It turns

Tracy: It turns

John: Out it

Tracy: Out

John: Also

Tracy: It

John: Exhibits

Tracy: Also exhibits

John: Properties of a ways

Tracy: Of a wave

John: Both

Tracy: It can do both

John: A particle

Tracy: A particle and

John: Wave.

Tracy: A wave.

John: That means

Tracy: That

John: You

Tracy: Mean

John: See it's manifesting itself as a form of matter. Yes but it's also a form of energy like

Tracy: And this is different than like matter having energy

John: Matter and energy here actually the same thing just different manifestations of that same thing. It's like one mouth that can both smile and frown but get this at the same time.

Tracy: Wow okay

John: So think of that

Tracy: Thick

John: Electron as a condensed bit of energy or as a condensed packet of energy

Tracy: Of energy.

John: That makes

Tracy: Okay

John: Sense

Tracy: That makes

John: And

Tracy: Sense

John: You'll begin

Tracy: And you'll

John: To

Tracy: Begin

John: Understand

Tracy: To understand

John: Why

Tracy: What

John: The electron is restricted to particular energy states here. Listen listen to this whistle. You're ready. They're just the the continuous

Tracy: The continuous

John: Sound from a high

Tracy: From.

John: Pitch to a low pitch Now what I'm going

Tracy: Now

John: To do

Tracy: What I'm

John: Is

Tracy: Going to

John: I

Tracy: Do

John: Won't do

Tracy: Is

John: That

Tracy: I would

John: Same

Tracy: Do that same

John: Whistle down a tube.

Tracy: A.

John: So we have

Tracy: So

John: A tube

Tracy: We have

John: Here

Tracy: A tube

John: In the studio.

Tracy: Here in the studio.

John: You ready.

Tracy: You're ready any

John: All right.

Tracy: All

John: I

Tracy: Right.

John: Hear the

Tracy: I

John: Same

Tracy: Hear the same

John: Sound going down

Tracy: Going down

John: The pitch going

Tracy: The pitch

John: Down.

Tracy: Going down.

John: What am I listening

Tracy: What am I listening

John: For. Listen

Tracy: Can you help

John: Listen

Tracy: Me

John: To the

Tracy: Listen

John: Steps.

Tracy: To the steps.

John: Here's without

Tracy: Here's.

John: The Tube. Here's with OK. So

Tracy: Okay.

John: Rather

Tracy: So rather

John: Than being

Tracy: Than

John: Smooth

Tracy: Being smooth

John: All the way down

Tracy: All the

John: There's

Tracy: Way down

John: Little

Tracy: There's

John: Gaps.

Tracy: Little gaps.

John: It's like

Tracy: It's

John: A little

Tracy: Like

John: Bit

Tracy: A

John: Choppy

Tracy: Little bit choppy. Is that what you mean. Yeah.

John: Yeah.

Tracy: Okay.

John: What we're finding

Tracy: What we're finding

John: Is that when

Tracy: Is that.

John: You confine the whistle to the tube you're quantized ing the whistle. Okay. Can

Tracy: Okay.

John: You do that

Tracy: Can

John: One

Tracy: You

John: More

Tracy: Do that

John: Time.

Tracy: One more

John: Now

Tracy: Time.

John: That I

Tracy: Now that

John: Know

Tracy: I

John: What I

Tracy: Know what I

John: Think I know

Tracy: Think

John: What I'm

Tracy: I

John: Listening.

Tracy: Know what I'm listening

John: Okay here's

Tracy: For

John: Without

Tracy: Hours

John: The Tube

Tracy: Without the two

John: Here's with

Tracy: Is

John: The tube.

Tracy: With the two. Wow.

John: I heard

Tracy: Okay

John: That.

Tracy: I heard that.

John: Yeah. So

Tracy: Yeah.

John: With a

Tracy: So.

John: Tube you've essentially quit you have actually quantized your whistle. So confine the whistle to the tube and it's quantized. You hear it's quantized. So

Tracy: Okay so

John: We're hearing

Tracy: We're

John: What

Tracy: Hearing

John: You say

Tracy: When you say we're hearing

John: As

Tracy: It Quantas

John: We hear it

Tracy: We

John: And

Tracy: Hear

John: When

Tracy: It in one

John: And

Tracy: Tone

John: Then

Tracy: And

John: There's

Tracy: Then

John: Nothing

Tracy: There's

John: For

Tracy: Nothing

John: A second

Tracy: For a

John: And

Tracy: Second

John: Then we hear

Tracy: And

John: It

Tracy: Then

John: In

Tracy: We

John: And

Tracy: Hear it

John: Essentially.

Tracy: In another town.

John: Yeah. There's steps

Tracy: Yeah. There

John: There's steps.

Tracy: Are steps

John: So here's the deal. Likewise confine an electron in the electron wave to an atom. You get the same result. Only certain

Tracy: Only

John: Wave

Tracy: Certain

John: Frequencies are permitted and bam.

Tracy: Yeah.

John: So there'll be

Tracy: So

John: Gaps

Tracy: There'll be gaps

John: In certain

Tracy: In

John: Places.

Tracy: Certain places.

John: You've got the

Tracy: Got

John: Quantized

Tracy: The

John: Asian you've got Niels bores quantized states you've got atomic spectra. The those those fingerprints

Tracy: Oh

John: I get

Tracy: I think

John: It.

Tracy: I get it.

John: Underlying it all

Tracy: It

John: Is the electron

Tracy: Electoral

John: Having these wave properties in if it has a wave property. That means you can have steps like a whistle down a tube so when you

Tracy: So

John: Say

Tracy: When you say

John: An element

Tracy: An element

John: Has a fingerprint

Tracy: A fingerprint.

John: What we're

Tracy: What

John: Seeing

Tracy: We're seeing

John: From the light

Tracy: From the

John: Spectrum

Tracy: Light spectra

John: Is certain

Tracy: Colors

John: Or certain

Tracy: Or certain

John: What we were

Tracy: What

John: Hearing

Tracy: We were

John: Is.

Tracy: Hearing is tones.

John: Now we're gonna

Tracy: Now

John: See

Tracy: We're gonna

John: Certain

Tracy: See as certain frequencies

John: Of light

Tracy: Of

John: Discrete

Tracy: Light discrete

John: Frequencies like 450 one for ninety two. Nothing in between. All right. OK.

Tracy: Okay

John: Each

Tracy: And

John: One will

Tracy: Each

John: Have

Tracy: One will have

John: Its own

Tracy: Its

John: Particular

Tracy: Own particular

John: Element

Tracy: Each element

John: Will have its

Tracy: Will

John: Own

Tracy: Have its

John: Particular

Tracy: Own particular pattern

John: Of those

Tracy: Of

John: Frequencies.

Tracy: Those frequencies.

John: Exactly because in one atom it's like

Tracy: It's like

John: You're whistling down a long tube another atom you're you're whistling down a shorter tube you have a bassoon you have a flute you have a French horn. All different

Tracy: All different

John: Characteristics with different tones

Tracy: Different tones.

John: If you will.

Tracy: Well

John: That's awesome. That's really

Tracy: That's

John: Helpful.

Tracy: Really helpful.

John: Okay great.

Tracy: Okay

John: That's

Tracy: Great. That s

John: Section four point whatever. All right. So these electrons are restricted to these particular orbits or let's say states within the atom. What are those states actually look like. You might be tempted to be thinking of a planet going around the sun as not bad but it's not quite accurate how the electron spends its time in a particular state is spelled out by what we call an atomic orbital now an orbital is a wave form it's like the cloud it's three dimensional it's mathematical very much so remember we're glossing over a lot of this at its core the orbital defines where an electron is 90 percent of the time when it's in a particular state of energy and you can have orbitals that are spherical. It's fairly easy to understand but do the math you'll find there actually orbitals that look like a dumbbells they're orbitals that look like balloons funny shapes watch the videos at conceptual Academy and you'll see where we display the number of these bizarre looking shapes. But what you're looking at when you're looking at an atomic orbital is the three dimensional wave of an electron at a particular energy level. I think that's enough to say about atomic orbitals. If you go into general chemistry and beyond you'll be digging much deeper into why they look like that and you know what we're even going to move past on energy diagrams for the multi electron atom.

John: I don't personally teach this in my own course and I think for subsequent additions you might not even see the electron configurations shown here. What am I talking about. The one is two to us one two P6 is common material used in gen chem. If you're advancing further into chemistry. Be sure to look over this section on how it is atomic orbitals can get filled based upon their energy levels. But for our purposes I want to just jump straight ahead to what we call the noble gas shell model of the atom we began this chapter with physical models and conceptual models. This shell model is noble gas shell model is a conceptual model that I think really nicely summarizes what we need to know for understanding bonding of atoms into molecules and chemical reactions. Let's dig into that for just a bit here imagine an atom like this at the center you have the atomic nucleus with its protons and neutrons in surrounding that are a series of concentric shells. Let's say seven concentric shells by concentric. I mean the Al share the same center the atomic nucleus.

John: Now each shell can hold a given number of electrons. Bear in mind we're glossing over a lot here. A shell. Technically speaking is a combination of different orbitals of similar energy levels. Now don't worry about it but the first shell because of the orbitals it represents is allowed to hold two electrons. It's the shell that's closest to the nucleus which frankly electrons like. Now the second shell it can hold eight electrons and then beyond that the third shell it too can hold eight electrons. The fourth shell it can hold 18 the fifth 18 the sixth 32 the seventh 32. Why are those numbers 2 8 8 18 18 32 32 has everything to do with the number of atomic orbitals that make up that shell. And it also has everything to do with the universe and to which we were born into in another universe with different constants different physical laws you might have different numbers of electrons that can fit into the shells but for where we live the numbers are 2 8 8 18 18 32 32 those the number of electrons that can fit within these shells from innermost to outermost given that you can build any atom of the periodic table. Let's keep

Tracy: Let's

John: It simple

Tracy: Keep it

John: Starting

Tracy: Simple starting

John: With hydrogen. Hydrogen hydrogen atoms got one electron that electron is gonna want to be as close to the nucleus as possible. Why. Because it's

Tracy: Because

John: Attracted

Tracy: It's attracted

John: To the positive

Tracy: To the positive

John: Proton right because

Tracy: Right.

John: It's attracted to the positive proton in the nucleus. So there you have it a hydrogen atom.

Tracy: What if there's a neutron

John: Does

Tracy: In there.

John: That cancel

Tracy: Does that cancel

John: Out the positive

Tracy: Out the positive

John: Charge that the neutron is neutral so it doesn't play a role. It just is contributing to the mass. No we're talking about here is the electrical attractions between the electron negatively charged and the proton in the nucleus which is positively charged So let's build a helium atom. Show me how many protons in the nucleus of a helium atom

Tracy: 2

John: That would

Tracy: That

John: Mean

Tracy: Would

John: For a neutral Helium atom you've got two electrons. So the first electrons gonna want to go in the first shell. Now add the second electron where is it going

Tracy: Got

John: To go

Tracy: To go.

John: For

Tracy: There's room for two

John: Days

Tracy: So it

John: In

Tracy: Stays

John: The first.

Tracy: In the first shell

John: You have just

Tracy: You've

John: Built

Tracy: Just

John: Yourself

Tracy: Built yourself

John: A helium

Tracy: A helium atom

John: Helium

Tracy: You

John: Atom. So the shell model of the helium atom has the nucleus in the center with a plus two charge and surrounding that in the first shell are two electrons. Now let's move to lithium lithium. Number three atomic number three has three protons that means for the neutral lithium atom you've got three electrons. How might those electrons be configured in a lithium atom.

Tracy: The

John: Electronics

Tracy: Third electron

John: Are gonna have

Tracy: Is

John: To

Tracy: Gonna

John: Go

Tracy: Have

John: To

Tracy: Go

John: The next

Tracy: To the next

John: Orbital.

Tracy: Shell

John: Why can't we just take that third electron and put it in the first shell. Because that third electron loves the positive charge of the nucleus doesn't want it to be doesn't it want to be there

Tracy: Of course it does. But based on experiments that have been done evidence suggests

John: Only

Tracy: That

John: So

Tracy: Only two

John: Electrons can be there.

Tracy: Can be there.

John: So in this universe we find only two electrons can reside in that first shell. So that third electron and the lithium atom is forced to reside in the second shell. So let's think about this. The helium atom has two electrons and they're both in the first shell. The lithium madam has three electrons two are in the first shell and one the third is in the second shell. So which is heavier lithium for helium

Tracy: Lithium has more protons and neutrons

John: So it's heavier. Right. OK. Let me ask you this. Which might be the larger Helium atom or a lithium atom.

Tracy: The lithium atom has another shell. So the electron is is uh spinning around further out from the uh nucleus. So it's

John: It's

Tracy: Bigger.

John: Sweeping

Tracy: It's sweeping

John: Out a

Tracy: Out

John: Greater

Tracy: A

John: Volume

Tracy: Greater

John: Of

Tracy: Volume

John: Space

Tracy: Of space.

John: That 30

Tracy: Yes

John: Electron

Tracy: 30 electron

John: Is. Yes. While the nucleus is defined pretty much the mass of an atom. What defines the size of an atom. That's the role of the electrons. Let's let's do a couple

Tracy: Let's

John: More.

Tracy: Do a couple more.

John: So we went

Tracy: So

John: From

Tracy: We

John: Hydrogen

Tracy: Went from hydrogen

John: To helium to lithium.

Tracy: To lithium.

John: Let's do

Tracy: Let's

John: Beryllium now beryllium

Tracy: You

John: Has

Tracy: Really

John: An atomic number four. So it's got four protons. Let's see how the electrons fill up the Bernoulli madam. Go ahead.

Tracy: Two

John: Electrons can be

Tracy: Can

John: The first.

Tracy: Be in the first shell

John: And the second

Tracy: The second two

John: Is going

Tracy: Electrons

John: To be in the

Tracy: Can

John: Second

Tracy: Be in the

John: Shelf.

Tracy: Second shell.

John: So beryllium has

Tracy: Really

John: Four electrons. Two are going to be in the first show. The remaining two the third and fourth are going to be in the second shelf. Now that second shell can hold

Tracy: Eight

John: How many electrons. Eight eight. All right. So

Tracy: All

John: We

Tracy: Right.

John: Still have plenty of room in that second shell.

Tracy: Thank you

John: Right. So envision

Tracy: So

John: The first shell is filled for the brilliant but the second shell has two electrons in it and there's still room for six more. Here's the question

Tracy: Much.

John: Which might be larger. A lithium atom or a beryllium Madam

Tracy: Well they both

John: Outer

Tracy: Have two

John: Shells.

Tracy: Outer shells.

John: They both

Tracy: They

John: Have

Tracy: Both

John: Two shells with electrons in them. The lithium has one electron in this second shell. The brilliant

Tracy: Really

John: Has two electrons in the second shell. How many proteins

Tracy: How many protons

John: Are there

Tracy: Are there

John: In lithium.

Tracy: In

John: There are three protons and beryllium.

Tracy: Really

John: There are four.

Tracy: So I'd say they're the same size

John: Let's look at the forces here. How do you suppose electrons feel about electrons. They're the

Tracy: They're

John: Same

Tracy: The

John: Charge

Tracy: Same church

John: So they would

Tracy: So

John: Repel

Tracy: They would repel

John: Each other.

Tracy: Each other.

John: They don't really like each other. So

Tracy: They want

John: They want to spread

Tracy: Us

John: Apart

Tracy: To wave.

John: Away from each other as much as possible. So that's

Tracy: So

John: One

Tracy: That's

John: Thing

Tracy: One.

John: To think about. Here's the other

Tracy: The

John: Thing

Tracy: Other

John: To think

Tracy: Thing

John: About. How do you electrons feel about

Tracy: That's

John: The atomic nucleus quite attracted

Tracy: Why attracted

John: To this.

Tracy: To those protons.

John: Why. Because it's a

Tracy: Because

John: Positive

Tracy: It's a positive

John: Charge attracting a negative

Tracy: A

John: Charge

Tracy: Negative charge of the electron

John: Because of the electro magnetic force whatever that is. It's actually one of the fundamental forces in the universe and we're using that we're invoking the electromagnetic force here to explain how it is that an electron likes the nucleus the electrons negative. The nucleus is positive right. Right now I want

Tracy: Now what

John: You to put yourself in the point of view of one of those electrons in the second shell. Are you there.

Tracy: Mm hmm mm hmm.

John: What do you see

Tracy: What do you see. Mm hmm. Well sometimes I see the nucleus the

John: Nucleus.

Tracy: Atomic nucleus.

John: Yeah sometimes

Tracy: But sometimes those

John: Electron

Tracy: Other electron

John: Orbitals are

Tracy: Blocking

John: My way.

Tracy: My way.

John: Now when you look

Tracy: When

John: Down

Tracy: You look down

John: To the nucleus

Tracy: To the nucleus

John: From that second

Tracy: From this

John: Shell

Tracy: Package

John: Would you agree

Tracy: You

John: There's

Tracy: Agree

John: The first shell

Tracy: Show.

John: That's in between you and that nucleus. Yes.

Tracy: Yes.

John: Ok so what's the charge on that first shell. Negative

Tracy: Too.

John: There are

Tracy: There

John: Two electrons

Tracy: Are two electrons

John: There are

Tracy: There.

John: Not

Tracy: Are there not. There are two

John: And

Tracy: To

John: How

Tracy: It.

John: Do you

Tracy: And

John: Feel

Tracy: How do you

John: About

Tracy: Feel.

John: That. There you are

Tracy: There

John: In the

Tracy: Are

John: Electron

Tracy: Electrons

John: To the second shell looking downward

Tracy: Looking down

John: Toward the

Tracy: Toward

John: Nucleus which you love. But in the way

Tracy: The way

John: You see

Tracy: You see.

John: Two electrons yum yum or yuk yuk

Tracy: Yeah.

John: Yuk you

Tracy: Yeah. It's

John: See

Tracy: Like

John: It's

Tracy: Two

John: A tall

Tracy: It's like

John: People

Tracy: Two

John: Sitting

Tracy: People

John: With

Tracy: Sitting

John: Hats.

Tracy: With hats in front of you at a movie theater. Excellent.

John: You want to

Tracy: You

John: See

Tracy: Want to

John: The

Tracy: See

John: Screen. The nucleus. But people are in the way. All right let's quantify this a little bit shall we. How many electrons are pushing you away from

Tracy: These

John: That nucleus too.

Tracy: Two.

John: So there

Tracy: So

John: You

Tracy: There

John: Are

Tracy: You are.

John: An electron

Tracy: Do

John: In

Tracy: You

John: A

Tracy: Like

John: Lithium atom and you're in the second shell

Tracy: You.

John: And you look to the nucleus and there are two

Tracy: Do

John: Electrons

Tracy: You like

John: In that first shell and they're pushing you away. So that's a minus two pushing you away. But what's there in the sweet nucleus. Beautiful

Tracy: Those beautiful protons.

John: How many

Tracy: How many. I forgot

John: Were in the lithium

Tracy: Where the lithium

John: Atom.

Tracy: Okay. Three.

John: So you

Tracy: Three.

John: Look the periodic

Tracy: See what the

John: Table

Tracy: Periodic

John: And

Tracy: Table

John: See the atomic

Tracy: Is

John: Lithium is three so there the three protons which is bigger.

Tracy: Which is big

John: Three or two three three. All

Tracy: Three.

John: Right. So

Tracy: All right. So

John: There you are

Tracy: There

John: That

Tracy: You

John: Electron

Tracy: Are that electron

John: And you see

Tracy: You see

John: A plus three pulling you

Tracy: When

John: Into

Tracy: You

John: The nucleus that you see minus

Tracy: See minus

John: Two pushing

Tracy: Two

John: You away from the nucleus who wins plus

Tracy: The

John: Three.

Tracy: Plus three. Yeah.

John: So you're held there by the nuclear charge of plus one. I know that real nuclear charges is three but from your point of view the effective nuclear charge the reality of it from your point of view

Tracy: You

John: As an electron

Tracy: As an electron

John: Out there in

Tracy: Out

John: The second

Tracy: There in the

John: Shell

Tracy: Second shell.

John: You're seeing

Tracy: Your C

John: A plus one because there's

Tracy: Because

John: Negative

Tracy: There's negative

John: To push

Tracy: To

John: Me

Tracy: Push

John: Out

Tracy: Me

John: There's

Tracy: Out.

John: A plus

Tracy: There's

John: Three

Tracy: A plus

John: Pulling

Tracy: Three

John: It

Tracy: Point

John: In net plus one. So you're held there because plus one is better than none. All right.

Tracy: Mm hmm mm hmm.

John: All right. Now let's do

Tracy: Now

John: The

Tracy: Let's

John: Same

Tracy: Do

John: Game.

Tracy: The same game.

John: Well not a lithium

Tracy: Well not a lithium

John: Atom but

Tracy: Atom

John: A brilliant

Tracy: But a beryllium

John: Atom plus

Tracy: Okay.

John: Four

Tracy: Plus four

John: For a proton

Tracy: Four protons.

John: Now they're for

Tracy: Now they're

John: Protons

Tracy: Four protons

John: For

Tracy: Four

John: Protons in the nucleus

Tracy: In the nucleus

John: And you

Tracy: And

John: Are

Tracy: You

John: One

Tracy: Are

John: Of those

Tracy: One

John: Electrons

Tracy: Of those electrons

John: In the second shell and you

Tracy: And

John: Look toward

Tracy: You look

John: That

Tracy: Toward

John: Nucleus.

Tracy: That.

John: What do you see.

Tracy: What do you see. There are two

John: Electrons

Tracy: In that

John: And

Tracy: Sack

John: That first

Tracy: And that

John: Shell

Tracy: First show.

John: Those pesky two electrons in your way. All right. So what's the net

Tracy: What's the

John: Result

Tracy: Net result.

John: That results

Tracy: The net result. So there's two electrons

John: In the way

Tracy: In the way. But there's

John: For

Tracy: Four

John: Protons. I want

Tracy: That I

John: To

Tracy: Want

John: Get

Tracy: To get to

John: That I'm

Tracy: Or

John: Attracted

Tracy: That I'm attracted

John: To. Yeah. As an electron

Tracy: As an electron then

John: It's a

Tracy: It's

John: Plus

Tracy: A plus

John: 2.

Tracy: Two.

John: So the

Tracy: So

John: Effective

Tracy: The

John: Nuclear charge that you see from your vantage as the second electron in this second shell of a

Tracy: Three

John: Atom is plus two.

Tracy: Plus two.

John: Ok.

Tracy: Okay.

John: I'm only

Tracy: So

John: Being

Tracy: I'm only

John: Blocked

Tracy: Being

John: By

Tracy: Blocked

John: Two.

Tracy: By two still

John: But there's a plus

Tracy: But there's

John: For

Tracy: A plus

John: There and so the net result is

Tracy: S

John: There's a effective

Tracy: S

John: Nuclear charge of plus two. So let's

Tracy: S

John: Compare

Tracy: S

John: That to what we had

Tracy: S

John: Before with lithium. That electron in the second shell

Tracy: S

John: Looks down

Tracy: S

John: And sees a plus

Tracy: S

John: One. Now we're in a beryllium. That second electron

Tracy: S

John: Looks down

Tracy: S

John: And sees

Tracy: S

John: A

Tracy: S

John: Plus

Tracy: S

John: Two which

Tracy: To

John: Is bigger

Tracy: Which is

John: One

Tracy: Bigger

John: Or two.

Tracy: 1 or 2

John: So

Tracy: 2

John: It has

Tracy: So

John: A stronger

Tracy: It has a stronger a stronger pull toward

John: Center.

Tracy: The center

John: Excellent.

Tracy: Nucleus.

John: Exactly. Exactly. That's it. Bingo. So those electrons in the second shell of brilliance are pulled in tighter toward that

Tracy: Toward

John: Nucleus.

Tracy: That

John: Why.

Tracy: S

John: Because that

Tracy: S

John: That's

Tracy: S

John: Got effectively

Tracy: S

John: Twice the charge.

Tracy: Which

John: And let's face it

Tracy: Let's

John: Your

Tracy: Face

John: Electrons

Tracy: It your electrons

John: You like

Tracy: You

John: Positive

Tracy: Like positive

John: Charge the more

Tracy: The more

John: Positive charge the more

Tracy: The more

John: The atoms

Tracy: The

John: Are going

Tracy: Atoms

John: To contract

Tracy: Are

John: The more those

Tracy: More those

John: Electrons are pulled

Tracy: Are

John: Inward. And that's

Tracy: In

John: Why

Tracy: That s

John: When you're asked

Tracy: When you pass

John: Which is

Tracy: Which

John: Larger

Tracy: Is larger

John: A lithium

Tracy: Will it

John: Atom

Tracy: Be

John: Or

Tracy: Really

John: Beryllium

Tracy: M

John: Atom

Tracy: M.

John: Your answer

Tracy: Your answer

John: Is lithium.

Tracy: Is larger.

John: He

Tracy: Yeah

John: Really

Tracy: Relieve

John: Am atom

Tracy: M

John: Is smaller

Tracy: S

John: Because they're experiencing

Tracy: You're experiencing

John: A greater what we call effective nuclear charge.

Tracy: It

John: And you can go from beryllium

Tracy: Go for. Really.

John: To boron which is number five and

Tracy: I

John: You'll see the effective

Tracy: See.

John: Nuclear charge jumps to plus

Tracy: S

John: Three.

Tracy: S

John: And then the next elements

Tracy: S

John: Plus

Tracy: S

John: Five

Tracy: S

John: Plus eight just

Tracy: S

John: Gets

Tracy: S

John: Bigger

Tracy: S

John: And bigger and so as

Tracy: S

John: You move from left to right across the periodic

Tracy: S

John: Table you're going to find the atoms get

Tracy: S S

John: Smaller

Tracy: S S

John: And smaller and smaller

Tracy: Because

John: The effective

Tracy: The effective nuclear

John: Charge gets bigger and bigger

Tracy: Larger

John: And bigger larger.

Tracy: And larger

John: Yeah

Tracy: And larger and

John: Bigger

Tracy: And bigger.

John: But there's a

Tracy: But

John: Limit

Tracy: There's

John: Now

Tracy: A limit

John: Isn't

Tracy: Now

John: There.

Tracy: Isn't there.

John: What's that

Tracy: What

John: Limit

Tracy: S that limit

John: For the second

Tracy: For the

John: Shell

Tracy: Second shell

John: Is eight

Tracy: Is

John: Electrons.

Tracy: Eight electrons.

John: Only eight

Tracy: Only

John: Electrons

Tracy: Eighty

John: Can be there. And by the time you get to the far right side of the periodic table you are now at the neon atom right. Neon has an atomic number of 10. Guess so many protons are in the nucleus of a neon

Tracy: Seven

John: Atom.

Tracy: Out of

John: Ten.

Tracy: 10.

John: Excellent. Then the first

Tracy: Then the

John: Shell

Tracy: First shell

John: Has how many

Tracy: Has

John: Electrons.

Tracy: How many electrons

John: Two

Tracy: To

John: In the second

Tracy: In the second

John: Shell can hold

Tracy: Can

John: How

Tracy: Hold

John: Many

Tracy: How

John: Electrons.

Tracy: Many electrons

John: Eight and nine has a total

Tracy: As the

John: Of

Tracy: Two

John: 10 electrons. Two are in the first

Tracy: The

John: Shell.

Tracy: First show

John: Eight are in the second

Tracy: The second

John: Shell. That second

Tracy: That

John: Shell is

Tracy: S

John: Filled to capacity in

Tracy: S

John: The neon atom. It's pretty

Tracy: S

John: Small.

Tracy: S

John: Let's go from

Tracy: S

John: Neon to sodium

Tracy: S

John: Sodium is

Tracy: S

John: Number 11 in the periodic table.

Tracy: S

John: So where's that.

Tracy: S

John: Eleventh electron

Tracy: Go

John: Well the first

Tracy: Well the first

John: Two are in the

Tracy: Are in

John: First

Tracy: The first shell the second eight

John: Seconds

Tracy: Are in the second shell.

John: To

Tracy: So

John: Eight

Tracy: That s two plus

John: And

Tracy: Eight

John: Then

Tracy: Is ten

John: We need

Tracy: And then

John: One

Tracy: We need

John: More

Tracy: One more

John: Sodium

Tracy: Because sodium

John: Is eleven

Tracy: Is eleven

John: Protons therefore eleven

Tracy: Therefore

John: Electrons.

Tracy: We love the electrons

John: So it has

Tracy: So

John: To go

Tracy: It has

John: On a

Tracy: To

John: Third

Tracy: Go on a

John: Show.

Tracy: Third shell.

John: So which is

Tracy: Which

John: Larger

Tracy: Is larger

John: A sodium

Tracy: The sodium

John: Atom or a neon

Tracy: The

John: Atom sodium

Tracy: The sodium atom.

John: Why. Because it's

Tracy: Cause it it's

John: Got no

Tracy: Got now

John: Third

Tracy: A third

John: Show.

Tracy: Shell.

John: I

Tracy: So

John: Mean

Tracy: That means

John: Excellent.

Tracy: That the

John: Most

Tracy: Outermost electron

John: Is sweeping

Tracy: Is sweeping

John: Across a larger

Tracy: A larger

John: Area or a larger

Tracy: Or a

John: Volume.

Tracy: Larger volume

John: So

Tracy: Of

John: That's

Tracy: Space.

John: The key

Tracy: That's the key

John: Right there.

Tracy: Right.

John: Is that when you went

Tracy: When

John: From neon

Tracy: You

John: To sodium suddenly you went one shell larger and that's that that's a jump in size. A quick jump in size. So you'll find that the sodium atom is markedly larger than the neon atom. But notice also something we've pointed out here you pointed out here that it's effective nuclear charges plus one. Didn't we hear that before. That was with the LA LA LA

Tracy: Look.

John: La

Tracy: The theme

John: Lithium that also

Tracy: That also

John: Had an effective nuclear charge of plus one. And we can wrap it all up right now look to the periodic

Tracy: Looked at the periodic

John: Table atoms above and

Tracy: Above

John: Below

Tracy: And

John: One

Tracy: Below

John: Another

Tracy: One

John: In

Tracy: Another

John: The periodic table have pretty much

Tracy: Pretty

John: The

Tracy: Much

John: Same

Tracy: The

John: Effect

Tracy: Same

John: Of

Tracy: Effect

John: Nuclear charge.

Tracy: In your charge.

John: What you'll find

Tracy: What you'll

John: Is

Tracy: Find

John: As you move

Tracy: Is as you

John: From

Tracy: Move

John: The top

Tracy: From the top

John: To the bottom

Tracy: To the bottom

John: On a

Tracy: Of

John: Tomic

Tracy: The

John: Group

Tracy: Atomic group

John: The atoms

Tracy: The atoms

John: Get larger.

Tracy: Get larger.

John: Why

Tracy: Because

John: They keep

Tracy: They keep

John: You batting

Tracy: They keep adding shells

John: They're more

Tracy: The

John: Shells

Tracy: More

John: So

Tracy: Shells

John: There

Tracy: So

John: Are three

Tracy: There are three

John: Shells in sodium with electrons filled but for lithium there are only two shells for hydrogen. It's only one shell so atoms of elements above and below one another in the periodic table. They'll

Tracy: How

John: Have similar effective nuclear charges which is actually

Tracy: Is actually

John: Why they have similar chemical properties and physical properties but they're not exactly

Tracy: Not exactly

John: The same

Tracy: The same

John: Because the

Tracy: Because

John: Atoms

Tracy: The

John: Get bigger as you go down the group. Why did they

Tracy: You

John: Get bigger.

Tracy: Get bigger

John: Because they're

Tracy: Because

John: More

Tracy: There

John: Successive

Tracy: Is so

John: Shells

Tracy: Much

John: Of electrons as you go down group and as you move

Tracy: As

John: From

Tracy: You

John: Left

Tracy: Move from

John: To right

Tracy: Left to

John: Across

Tracy: Right

John: The periodic

Tracy: Across

John: Table you'll

Tracy: The

John: Find the atoms

Tracy: Bottom

John: Tend to contract because

Tracy: You

John: The effect

Tracy: Think

John: A nuclear charge.

Tracy: You should

John: Put that all

Tracy: Put

John: Together

Tracy: That all together

John: You'll find

Tracy: You find

John: Your largest

Tracy: Your largest

John: Atoms are to the

Tracy: Search

John: Lower left of the periodic table and your smallest atoms are to the upper right. All explained by this idea we call the shell model that's the essence of section four point nine. And that's the grand conclusion of chapter four in chapter

Tracy: In Chapter

John: Six

Tracy: 6

John: Who will be

Tracy: We'll be

John: Digging into a shortened

Tracy: A short

John: Version of this shell

Tracy: List

John: Model called electron dot diagrams simplified even further

Tracy: Even for

John: But very

Tracy: The

John: Useful

Tracy: Very use

John: In terms

Tracy: In

John: Of

Tracy: Terms

John: Understanding

Tracy: Of understanding

John: The nature of chemical bonding. To wrap

Tracy: To

John: Up

Tracy: Wrap

John: This

Tracy: Up

John: Wrap

Tracy: This

John: Up

Tracy: Wrap

John: Remember

Tracy: Up. Remember

John: Their physical

Tracy: The physical

John: Models and there are

Tracy: And

John: Conceptual

Tracy: Their conceptual

John: Models a conceptual model describes the behavior

Tracy: The behavior

John: Of a system.

Tracy: Of the system.

John: Now the system

Tracy: This

John: We're talking

Tracy: Is what we're

John: About

Tracy: Talking

John: Here

Tracy: About

John: With atoms

Tracy: Here about

John: Are a group

Tracy: The

John: Of subatomic

Tracy: Group of subatomic

John: Particles held tightly

Tracy: So

John: Together

Tracy: Tightly together

John: And in very

Tracy: A

John: Very very small region of space so small

Tracy: So

John: That

Tracy: Small

John: We enter

Tracy: That

John: A

Tracy: Into

John: Realm

Tracy: A realm

John: Where quantum mechanics comes to play.

Tracy: Into play

John: And within those rules

Tracy: Those rules

John: Of quantum

Tracy: Of

John: Mechanics

Tracy: Quantum mechanics

John: We find

Tracy: We

John: That

Tracy: Find

John: Electrons

Tracy: That electrons

John: Can have only

Tracy: Could

John: Particular

Tracy: Only get

John: Amounts

Tracy: Together amounts

John: Of energy

Tracy: Of energy

John: And as a consequence of that electrons organize themselves within these shells about the atomic nucleus. Remarkable stuff. So

Tracy: Hey

John: How is

Tracy: So

John: The weather

Tracy: How is

John: Connected

Tracy: The weather connected

John: With an atom.

Tracy: With an atom. Mm hmm.

John: They both

Tracy: They both

John: Can be predicted

Tracy: Can be predicted

John: Using conceptual models. Yay.

Tracy: Yeah. Okay.

John: All right. So next chapter we'll be digging into the atomic nucleus. We have in store a field trip to the Rocky Flats area of Colorado where plutonium was produced for the manufacture of nuclear bombs. We're looking to visit actually a cyclotron in the area where they produce nuclear medicines talking about all sorts of fun stuff and important stuff when we get to the nuclear chapter. Coming up next.
John: Our theme music by Zach Geoffrey. Musical flourishes by and in memory of Charles Paxton. For more of his music look for Char-el, that's c h a r dash E L at places such as Spotify. Production assistance from Greg Simmons and c pro music for show notes and more please visit conceptual science dot 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