AUDIENCE: [INAUDIBLE]

MARK HARTMAN: OK. So electrons that are bound to atoms are only allowed to orbit in certain states, or at certain energies, with certain energies. OK? That's an important thing. That's what we mean-- did anybody read about what a quantum was? How does that have to do with what Steve just said? What do you think, Peter?

AUDIENCE: Quantum is the amount of energy that allows them to jump between the energy levels.

MARK HARTMAN: OK. A quantum leap is to jump between one energy level of an atom-- or an electron in a particular energy level in an atom, and it can jump to the next higher level. All right? Azif, what was the one or two things that you learned? I need everybody else to stop clicking, to stop reading. We want to be paying attention to the group. Nice and loud.

AUDIENCE: When electrons jump down a level, it gives out photons. The bigger the orbit, the higher the energy.

MARK HARTMAN: OK. The bigger the orbit, the higher the energy that that electron has to have. If the electron is in a high energy orbit and then it spontaneously jumps down-- which happens, because most things in the universe want to be in low states of energy. Being in a high state of energy is not stable. So when you have electrons that are at high energy levels-- which is why I was very careful before to not let you say photons have energy levels. Photons do not have energy levels. Photons have a certain amount of energy, not an energy level. OK?

I want everybody to stand up. We're going to go across the room, and we are going to do another kinesthetic model. Can anybody remind you what a kinesthetic model is as we go across the room? Come over here. And we are all going to be atoms of Shekibium. OK?

Shekibium is a special element that only exists here at the CAI. Each one of you is going to represent an electron that is orbiting around a nucleus of Shekibium. OK? And the energy levels of Shekibium-- if you are an electron-- so each one of us is going to represent an electron orbiting in a different atom. So you can either be in a small orbit, which means you have one electron volt of energy, or you can be in the next higher orbit-- the next larger orbit that we saw. Larger orbits have higher energies. Three electron volts. Or you can be in the next higher orbit, and you as an electron have to have 4 electron volts. OK?

AUDIENCE: All right.

MARK HARTMAN: But we are-- where are our cups?

AUDIENCE: Want them all?

MARK HARTMAN: Yup. Let's bring them over. Everybody gets a cup. No, you're not going to eat M&M's. You're going to give them away.

AUDIENCE: [MOANING]

MARK HARTMAN: The ones that you don't eat you don't have to give away. OK. Everybody gets one of these. So we're going to pretend to be a box of Shekibium. If our box of Shekibium has no extra energy, where are all the electrons going to be? Nice and loud.

AUDIENCE: Oh, I was just thinking to myself.

MARK HARTMAN: OK. If we have no extra energy, we're just a box of Shekibium-- no, I wouldn't do that one. That's very dangerous. Everybody's electron is going to be in the lowest energy level. So I want everybody to stand on this line. Everybody. You may have to squeeze. All right.

AUDIENCE: Exsqueeze me.

MARK HARTMAN: OK. Each one of you represents an atom of Shekibium. And what I'm going to do is, I'm going to add energy to our box of Shekibium. by shaking it up. Right?

AUDIENCE: [INAUDIBLE]

MARK HARTMAN: That's fine. I'm just going to call it Shekibium, because I imagine it's kind of different. You'll notice, though, that the energy levels here are different. It doesn't just go one, two, three, four. It goes one, three, and then four. Now, in the simulation you can add energy by shooting some photons at you guys. You can also add energy by shaking it up, or heating it up.

If you heat up, you guys are going to bounce around more. And if one atom bounces into another one, sometimes it can knock the electron into a higher energy level. So I'm going to shake all of you guys up, and randomly you are going to fill up some of these higher energy levels. Some of you can stay there. Some of you will get some energy, and you'll jump up to the higher level. Ready? Figure out which level you're going to go to in your mind. Can you see it? Can you see it?

AUDIENCE: [LAUGHTER]

MARK HARTMAN: And shake them up. OK. OK. Oh, you dropped a yellow. Oh! You crushed the yellow photon! All right. Now I stop. And what I want you guys to do is-- people-- Juan, are you in between levels or what?

AUDIENCE: Yeah.

MARK HARTMAN: Let's have you be up here at four. Each one of you has been given a different amount of energy. You guys didn't gain any energy. You guys gained some, and so you go on up here. You guys gained more, and you went up here. Now, you all have buckets of energy, right?

AUDIENCE: Delicious M&M's.

MARK HARTMAN: Delicious energy. So it is your decision now as an electron-- eventually, you are going to drop back down. Now, you can either drop back down to the next level down, or you could drop all the way to the bottom. But I want you to give out a photon of the correct energy if you drop a level. Will you guys in the back be able to give out any photons?

AUDIENCE: One.

MARK HARTMAN: No, because they can't drop back. They're already in the ground state. So Bianca, where do you want to go? You have to drop down.

AUDIENCE: There.

MARK HARTMAN: OK. So what color of photon, what energy-- oops. There are going to be our colors in the model. This is going to be our energy. How much energy do you have to give up to drop down to that lower level? What energy level are you at now?

AUDIENCE: Three.

MARK HARTMAN: Well, you're at three. How much energy do you have to give up to get down there?

AUDIENCE: Two.

MARK HARTMAN: So what kind of a photon do you have to give off?

AUDIENCE: Yellow.

MARK HARTMAN: Oh, nice. OK. So Nikki, where do you want to go?

AUDIENCE: Over there on three.

MARK HARTMAN: OK. So what color photon do you have to give off?

AUDIENCE: Brown.

MARK HARTMAN: OK. Juan, where do you want to go?

AUDIENCE: I want to stay here.

MARK HARTMAN: Oh, that doesn't happen. You can stay here for a while.

AUDIENCE: She drops down to three, though.

MARK HARTMAN: If you drop down to three-- what color?

AUDIENCE: Brown.

AUDIENCE: [INAUDIBLE]

AUDIENCE: Brown, because I'm on three.

AUDIENCE: Do I have to give?

MARK HARTMAN: Yeah, but you as an electron have how much energy right now?

AUDIENCE: Four.

MARK HARTMAN: But you would have how much? Juan, you're standing on our numbers.

AUDIENCE: Three. I would give up red?

MARK HARTMAN: So you have to give up one electron volt. It's not that you're giving off the energy of that level. You are just giving off the energy of the difference between the levels. OK? So I shook you up. Now you can all decide where you want to go. Juan, if you wanted to go all the way back down to one, what energy would you give off?

AUDIENCE: I would give yellow, because I have-- no, wait.

MARK HARTMAN: How much energy do you have right now?

AUDIENCE: Four.

MARK HARTMAN: Four electron volts of energy.

AUDIENCE: I would give brown.

MARK HARTMAN: You would give brown, because you're going to go from four to one.

AUDIENCE: Yeah.

MARK HARTMAN: OK? So what we're going to do-- well, no, we're not going to do that yet. Can you guys come up and be the collector?

AUDIENCE: [INAUDIBLE]

MARK HARTMAN: No, no, no, no. Now, everybody change their level. Give us what you need to give us. No, no, just one. You're going to give off one photon.

MARK HARTMAN: OK. All right.

AUDIENCE: No!

MARK HARTMAN: OK, we're ready. Now-- so everybody fell down except Nikki. What do you have to do now?

AUDIENCE: I can go down.

MARK HARTMAN: She could go down, but we're going to give the box another shake. And you guys get to choose where you're going to jump to.

AUDIENCE: [INAUDIBLE]

MARK HARTMAN: No, no, no. We're just going to do this element for now. Shake, shake, shake! Where do you want to go? Everybody should go up at least one, right? There we go. All right. But you would have jumped up. Now we wait for a while. You're electrons. You're happy. You're in the high energy state.

But now-- now think about where you're going to jump down to. You've got two decisions. You can jump down one level, or you can jump down two, if you're on the top. If you're on the middle, you can only jump down one. Ready? And emit.

MARK HARTMAN: OK?

AUDIENCE: I know, but [INAUDIBLE]

AUDIENCE: Red one.

MARK HARTMAN: So-- what? No. Where were you? You were on one. So you can't give off any. You're in the ground state. You have to stay there.

AUDIENCE: [INAUDIBLE]

MARK HARTMAN: OK. OK. You give--

AUDIENCE: [INAUDIBLE]

MARK HARTMAN: No, no, no. You only-- remember, though, when you jump to the level, you only gave-- the photons that were there only gave off-- or, I'm sorry, the electrons only give off one photon per jump. So I can't get three photons from an electron. I have to get one photon. So where were you, Steve?

AUDIENCE: Three.

MARK HARTMAN: Three. And you're now going to one. So how much energy do you have to give off?

AUDIENCE: Red. One.

MARK HARTMAN: So from three to one--

AUDIENCE: Two.

AUDIENCE: Yellow.

AUDIENCE: [INAUDIBLE]

AUDIENCE: What's three minus something equals one?

MARK HARTMAN: You're going back to one, but you have to-- if you have an energy of three electron volts to get back to one, you have to give off two. So you have to give us one yellow photon. One yellow, not the-- there we go. All right. OK. Let's-- now, you guys haven't dropped all the way back. That's OK. Now we're going to shake the box again, and you guys get excited, which means that you jump energy levels. We're going to inject-- we're going to shake the box. Some of you go up. Some of you don't.

AUDIENCE: I'll go to the top.

MARK HARTMAN: All right. Now we wait for a while, and you're going to give off some photons as you jump back.

AUDIENCE: Gamma photons!

MARK HARTMAN: Can you give off gamma ray photons?

AUDIENCE: Can I? Of course I can!

MARK HARTMAN: Are you sure?

AUDIENCE: No.

MARK HARTMAN: Where can you go from here to give off photons?

AUDIENCE: It's not fair. [INAUDIBLE]

MARK HARTMAN: OK. So what I-- no. You don't want to give two. You only give one.

AUDIENCE: He's out of yellows, though.

AUDIENCE: He's out of yellow, so--

AUDIENCE: Remember, we ran out--

MARK HARTMAN: Oh, there we go.

AUDIENCE: Yellow is what we have the least of.

MARK HARTMAN: OK. Yellow's what we have the least of. All right. So what we've-- OK. So at this point, what we've done is-- if we add energy to a box of gas, just like we did over there with our hydrogen. We added electrical energy. We add the energy. We wait for the photons to be given off by the atoms. All right? So what I want you guys to do-- they're going to build a spectrum of what you guys gave off. Now, each atom only gives off one photon at a time, and you don't always give off every photon. But if we had a box of you, we'd get a bunch of photons.

So I want everybody to look at this spectrum. Again, this is intensity, or number of photons we collected.

AUDIENCE: We substituted-- no, wait, there were two greens--

MARK HARTMAN: I know. I moved them. It doesn't matter. It's just the-- OK.

AUDIENCE: Mark, what happened with [INAUDIBLE]?

MARK HARTMAN: What's that?

AUDIENCE: What happened with [INAUDIBLE]? We have-- what's the name? Shekitians?

MARK HARTMAN: Oh. Shekibium. Shekibium and Peterium. Well, he'll get to be something next time. Yes. So why did we get photons of 2.0 electron volts? Somebody explain why.

AUDIENCE: Because of the higher intensity.

MARK HARTMAN: No. That's what we see. That's the observation. Right? We can observe. Juan, make an observation about this spectrum. Intensity versus energy. Say what you just said.

AUDIENCE: The yellow has a high intensity.

MARK HARTMAN: OK. So yellow-- ladies and gentlemen. Yellow has a high intensity. Why, now-- let's think about a model of light production. Why did we get 2.0?

AUDIENCE: Because we were changing--

AUDIENCE: Because you hadn't jumped [INAUDIBLE] I jumped back, so when I jumped back, you had to give yellow.

MARK HARTMAN: So when we went from three back to one, the difference was two, and we had to get that. Why do we have some three and some one?

AUDIENCE: [INAUDIBLE]

MARK HARTMAN: So you had to break from four to one, which gives us three, or--

AUDIENCE: From four to three.

MARK HARTMAN: From four to three. We didn't have to always jump back to the lowest level. OK. So let's look at this spectrum over here.