Tuesday will be the first weekly quiz, celebration that is. That will be at the beginning of recitation. You'll have 10 minutes. It'll be a short one-pager. You just write on the page. All you bring is your periodic table, which you should have gotten in recitation yesterday. Periodic Table, table of constants, calculator, something to write with, but no aid sheet on the weeklies.

Readings: Readings, I urge you to read before you come to class. And so if you go to the website, you can go to Schedule, and in the schedule, you'll see stuff like this that tells you what the readings are for the day. As I mentioned last day, the lectures are being videographed and posted probably within an hour on the website and any of the images that I show are also recorded, burned as PDFs and uploaded. So you don't have to be put in high-speed stenographic mode in order to attend class.

What's the other thing I wanted to tell you? If you're new to the class or if you need to change your recitation section because your conditions have changed, do not simply go to the other class. We're trying to regulate enrollment, particularly on Tuesdays. If the TA shows up expecting 20 students and has 20 copies of the quiz and 25 people show up, that's not a recipe for success. So you must go to my administrative assistant, Hilary Sheldon in order to change recitation. And if you need any of the handouts and so on, it's just down the hall here in Building 8, Room 201. I think that's all that I had to say. If you go here the videos are all listed.

So last day we started talking about taxonomy and that led us to the beginnings of atomic theory. We visited with Democritus, 400 BC. We had that detour with the idiocy of Aristotle, and then eventually got back to our senses, and we saw John Dalton with his table of the elements, and then ultimately onto Mendeleyev. And I wanted to pick up the thread there.

But before doing so, draw attention the fact that John Dalton did more than simply develop a set of fonts for us. So he proposed the model of the atom and this goes back little over 200 years ago, and these are the features of the model. First of all, that matter is composed of atoms that are indivisible and indestructible. So that goes all the way back to Democritus, nothing new there. All atoms of an element are identical. Atoms of different elements have different weights and different chemical properties. This is the emergence of modern material science, the connection between properties and elements. So the weight arguably is one of the properties, but the only way they could distinguish elements at that time was by their atomic mass.

Atoms of different elements combine in simple whole-number ratios to form compounds. Well, that makes sense because they're the elements. They are the elemental building blocks. If I told you you could build a structure made of blocks and part-way through your construction I say, why don't you cut that block in half, you'd say, well, then the block isn't the building block. It's the half-block that's the building block. So axiomatically if these are the elements they must combine in simple whole-number ratios to form compounds.

And lastly, atoms cannot be created or destroyed. Well, he wasn't foretelling E equals mc squared. What he was saying was that if you take elements and you combine them to form a compound, if you subsequently decompose the compound you get the elements back as they were. So those are the features of John Dalton's model.

And we fast forward to 1869. And this is the knowledge that was available at the time in terms of the elements that had been isolated and characterized. And it was with this set of elements that Mendeleyev operated. On file cards, in his breast pocket, he carried with him everywhere. And he wrote down the names of the elements and their atomic masses and their properties and whatever else he could use the way of characterizing them. And during the course of writing a textbook-- he had just finished a chapter on the alkaline metals and he was sitting in the railway station playing solitaire, and boom! The flash came to him that you don't put arsenic underneath aluminum even though it's next in mass to zinc. You move it over and you don't even put it under silicon. You put it under phosphorus. And furthermore, what he said was there's going to be an element here discovered under silicon and it will have these properties.

And let's look a little bit more deeply at the properties. But before doing so I want to say that by announcing this prediction of what the element should be that's missing is that we start to see the evolution of principles of modern chemistry. First of all, he recognized the pattern. So did Lothar Meyer in Tuebingen. So they both proposed a periodic table of the elements, but where Mendeleyev pulled away from the pack and distinguished himself was that he developed a quantitative model. And I haven't shown you the quantitative aspect yet. That's coming next. That explains the observations, and that's good. You might say, well, that's just curve fitting if you're a cynic. But it makes predictions that can be tested by experiment, tested by experiment.

So let's take a look. He said that under silicon, but above tin, there would be an element. He called it eka-silicon. Eka is a Sanskrit word, which means one after. So this is the element one after silicon. It was eventually isolated and given the name germanium. Mendeleyev said it would have an atomic mass of 72 grams per mole. In fact, it's 72.59. He said it would have a density of 5.5 grams per cubic centimeter. It's 5.36. This is 1869. He said that it would have a high melting point, whatever that means, and it melts at 958 Celsius. It's compounds. he said it would form a dioxide with a high melting point and a density of 4.7. It forms a dioxide and its density is 4.70.

In fact, there's a story about a French mineralogist who came upon some of the stuff that ultimately became germanium dioxide, measured its density and reported it to Mendeleyev in a letter, saying, you know I measured the stuff and it's 5.3 grams per cubic centimeter. Mendeleyev wrote him back and he said, make the measurement again. You're wrong. He wrote back three months later and said, I measured it again. It's 4.7. That was the genius of Mendeleyev. To go way out on a limb and make those predictions.

And so I've made the case for the table of the elements. Why do we call it the Periodic Table? What's the periodic about? Well, the periodic-- take a look here, if you go to the website there's a tab called Courseware and there's a tab called Periodic Table. And you can go to the Periodic Table and ask the software to plot property. So for example this is boiling point versus proton number or atomic number. And so you see the boiling point varies as you move from low atomic number to high atomic number. But it's not totally random. It's not a Gaussian distribution. There are features. It goes up and down, up, down, up and down. If you train your eye a little bit you'll actually see some regularity, a pattern there. Maybe that's not so good. Let's look at this one. This is electrical conductivity. And again, up, down, up, down and look at those red lines. There, there, there, there. Don't you see something? That's a pattern. And they're almost equally spaced. So that was where Mendeleyev announced his Periodic Law, where he said the properties are related to the identity of the atoms. And furthermore, he announced, that the properties are a periodic variation in atomic mass.

So let's get that now Mendeleyev's Periodic Law, and the properties of the elements vary periodically with atomic mass. That was Mendeleyev. So now that we know that we can go forward, and here's now the full-blown Periodic Table according to the framework that Mendeleyev established.

Now if you look at this carefully, you'll see down here things get whited out and there's these strange notations, uu, m, and all that stuff. What's that all about? This is where the super heavies lie. These are all synthetic elements. Transuranic, they're made by high-energy reactions, so-called high-energy physics in what you might call accelerators, atom smashers, what have you. And there's only three places on the planet where you can conduct such reactions. One of them is in Darmstadt in Germany. One is in Dubna, just outside of Moscow. And if you want to stay home-- and eschew the frequent flyer miles-- you can go to Berkeley, California. These are the three places where we have the accelerators capable of making such compounds.

And so, take a look carefully at what the nomenclature is. The way you name them is by using these Latin ordinals. So un, bi, tri, quad and so on. So if you wanted to name element 115, it's ununpentium. You want the ium ending. And you can make these up. You could make up element 205 if you want to or whatever. My favorite is 111 because that's unununium. But there they are, so you can have fun with those.

But with time, the elements are being named and these have been synthesized since your version of the table was printed. And so number 110 is named Darmstadtium in honor of the team at Darmstadt that first isolated it.

And number 111 was just named two years ago and the name is roentgenium after Wilhelm Roentgen, who discovered x-rays.

Now what is it about discovery? Well, here's an example of one such reaction that would give you an element. So if we had access to one of these devices we could take, for example, lead and nickel and accelerate them to very, very high energies. And then we could make 110, ununilium. Or now we'll call it Darmstadtium plus neutron. And in doing so we've generated the new element. But we can't just say we've made the element and publish. We have to be able to characterize it.

Remember the reason that we gave Cavendish the credit for discovering hydrogen wasn't that he's the first to know that hydrogen exists, but he isolated it and gave it value. So if you look at the rest of the periodic table, you get things like boiling point, melting point, density, electronegativity, first ionization energy. There's a lot of information there. If you go down here there's nothing. It's all blanks. These things have very, very short lifetimes. Fractions of a second. But you have to isolate them. There's certain criteria before you can publish.

And all this is regulated by this governing body called the International Union of Pure and Applied Chemistry, So UPAC, the organization that finally rules on the legitimacy of any of these. And actually there have been some retractions in recent years, where people published claiming-- I think there was a report out of Berkeley claiming that they'd synthesized 115 and then subsequently that was retracted because they couldn't support the property measurements

Last thing is, if you're interested, want to do some extra reading, there's a fantastic book about Mendeleyev. He was the youngest of 14 children, came out of a very poor family in Siberia and rose to be a giant of his day. He was a polymath. He, among some of the other things he did, he worked for the Ministry of Weights and Measures under the czar. The czar was interested in taxation of alcohol. And if you mix equal volumes of water and vodka you don't get additivity. So 100 mL of water plus 100 mL of vodka doesn't give 200 mL. It gives less.

And so Mendeleyev did a study to determine what the optimum ratio is so that people couldn't misrepresent the amount of alcohol in the beverage. And set the standard at 40% alcohol by volume, which is used the world over to this day.

He also came to the United States in 1876 to go to Titusville, Pennsylvania, where the first oil well was drilled. And did an exhaustive study of what was the American petroleum industry at the time. And then went back to Imperial Russia and did the same survey for the Czar in Imperial Russia, including a report that recommended how to develop the natural resources of the time. He was really an amazing man. He wrote text books and so on. And nobody in science-- I would venture to say-- has not heard of the periodic table.

Mendeleyev died in 1906. The Nobel Prizes were first offered in 1901. So there were five years where he was close to the top for winning the Noble Prize but was eked out by somebody else. When you look back at those other Nobel Prizes, they were deserved. But none more so than that for Mendeleyev. So ironically the man who gave us seminal knowledge of all chemistry was never awarded the Nobel Prize. And there's probably a lot of politics in there. And as I said last day, here's the typical picture of him. In this he sort of looks like a street person, disheveled and so on. But this was the man that gave us the periodic table. That's him at age 35 when he annunciated the Periodic Law. So good for him.

Alright. So now, let's take a look a little deeper about the properties of the elements. How do we understand the properties of the elements? For the properties elements we're going to have to look inside the atom. If you did your reading you undoubtedly came across this table. Which at first pass, deconstructs the atom into three simple particles: the electron, the proton and the neutron. Here are their symbols, e, p and n. And they're distinguished by charge and mass. So the electron has charge, minus 1.6 times 10 to the minus 19 Coulombs. And a very low mass: 9.11 times 10 to the minus 31 kilograms. The electronic charge is balanced by the protonic charge. The atom is net neutral. So the proton has a charge of plus 1.6 times 10 to the minus 19 Coulombs. The neutron, as the name implies, has 0 charge. The proton and the neutron have very nearly equal masses, however.

Right. And just a word about the units. The units here are given in terms of the Systeme Internationale. So when we use the term, C, capital C is for the Coulomb. And that's the unit of charge. And it has an uppercase letter because it's named after a scientist. In this case, the French scientist, Coulomb, whereas the gram is not named after a scientist and so it's lowercase. And then we can amplify by powers of three. So if I want 1,000 of these, I put a lowercase k here. If I put an uppercase K, I end up with the unit Kelvin, which is the unit of temperature named after Lord Kelvin. And all of this is known as SI units, which is the International System. And it's not because the scientists don't know how to develop an abbreviation. This was originally developed when French was the international language of science. So this is known as the Systeme Internationale and all of these units were defined at that time. And the term SI sticks that's the legacy.

All right, so now if we go to the Periodic Table. When we start looking at the elements, we can look at any entry on the Periodic Table, and we have the chemical symbol that I'm designating here as uppercase X, and this was originally John Dalton with the I and the circle around it. And about 30 years later the Swedish scientist Berzelius suggested that we use neutral units and so therefore we have the Latin coming in for many of the elements, such as iron, Fe, ferrum, and gold Au, aurum. In the upper-left corner, we have the quality I'm representing here, A And A is the mass number. Some people call it the atomic weight. And it is the sum of the masses of all the constituents. So it's the sum of the mass of the protons, so it's the proton number plus the neutron number plus the electron number. But since the electron weighs 1/1800 of what these others weigh, you normally don't consider this. It doesn't matter. So just adding protons plus neutrons gets you to what we call the atomic weight.

And then down in the lower left corner we have Z and Z is the proton number. And as the name implies, it's equal to the number of protons in the nucleus, which then equals the number of electrons outside the nucleus in the neutral atom. Now I'm specifying neutral atom, because it's not necessary for atoms to be neutral and we'll take a look at those in a moment.

A point about redundancy here. We don't really need the proton number and the chemical symbol because the proton number really defines. The proton number is like the Social Security number. This is the identity number of the atom. If we change the the proton number, we change its identity. So for example, I could write sodium. Sodium 23 and 11. I don't need the 11. 11 means it's sodium or sodium means it's 11. So I could just write this as 23 sodium. So I know it's sodium, that means it's got 11 protons and 23 minus 11 must be neutrons. Or if I wanted to be a smart aleck, I could write this : 23 11. That's sodium. I don't need to put anything here. But there's no smart alecks here, of course.

So for example, we could then show this reaction as-- this is what? 208. This is lead, 208. And nickel, 62 gives us Darmstadtium with a value of 269 and the neutron is 1. You can see how these reactions can be made to go. Now atoms don't necessarily have to be net neutral. We can have something that is net non-zero charge. Net non-zero charge on the atom gives it the term, ion. Ion is an atom with net non-zero charge. And we have two cases where the atom is net positive. If the atom is net positive that's the result of electron deficiency. The atom is electron deficient. And we term such an atom the cation.

There's two types of ions. The cation. And then we have something that is net negative. If it's net negative, it means it's electron-rich. That is to say, there are more electrons than protons and the net negative ion is called the anion. And you can try to figure out ways. I sometimes think that cation has a t, which looks a little bit like a plus sign. Anion has five letters, minus has five letters. And they both end in n, but this has an n, which is negative or something. You'll figure something out.

Now we've talked about varying charge at constant proton number. But the other thing we can do is we can look at-- you can vary the neutron number. Since the neutron has no charge you can vary the neutron number and not harm the identity and still have a neutral atom. So vary neutron number at constant proton number. And let's see what that is. That gives you something that looks like this. So for example, if you if you look at carbon, the atomic mass that's shown here is 12.011. And you'd say, well, gee, if it's got 6 neutrons and 6 protons, why isn't that 12 exactly? Well, this is the answer here. You can vary the neutron number at constant proton number.

So let's take a look at how that plays out. The way that plays out is as following. Let's see I'm going to make a little table here. So we'll start with carbon 12. Carbon 12, so that means-- now I know what I'm going to do. I'm going to bring this down and make some headings for me. This will be my proton number and this will be my neutron number. And finally I'm going to talk about abundance, natural abundance.

So carbon 12, since it's carbon, axiomatically it must have 6 protons. And 12 minus 6 is 6, so it's got 6 neutrons. And this is the dominant form of carbon. If you took a chemical analysis of the carbon you'd find that over 98%, 98.892% of the carbon atoms that you examined would be of this form, carbon 12. Now there's also carbon 13. Has to be 6, otherwise it's not carbon. That means it's got 7 neutrons. And it's a minority species. 1.108%. And then there's a third form of carbon and that's carbon 14. Again, has to be 6 and it's got 8 neutrons. And it's found in vanishingly small quantities, one part in 10 to the 12. Or we could call it ppt, parts per trillion.

So this is same atomic number, same proton number, same Z but different mass numbers. Different A's. So all of these variants of carbon are found on the same place, the same spot on the Periodic Table. The Greek word for same is iso, and the word for place is topo, so these are called isotopes. The isotopes of carbon are species that have identical proton number but different neutron number. How about the units? What are the units here? Well, we have to give some kind of unit. I've been sort of freely going around and counting protons as one and so on.

And here's the standard. The standard for mass is defined, and the definition goes like this. If you take carbon 12, which we just introduced to you, and we say that we're going to specify a mass of 12.000 grams exactly for a specified quantity, in other words, a specified number of these atoms. We have to say we'll take a certain number of these carbon atoms and specify the mass of that number is 12 exactly. And specified number of atoms being the mole. The mole. And it turns out that the mole has a value of 6.02 times 10 to the 23rd. How do they get that number? A little bit more in the way of definitions.

It was a concept put forth by a professor. So we're going to take some time on it because we respect professors, in this class at least. And so this was a concept put forth by Professor Amadeo Avogadro. Professor Avogadro, who was a professor of physics at the University of Turin, Torino. And he was a contemporary of John Dalton's and they were both studying gases. And it was Avogadro who taught us that, when you keep the pressure constant equal volumes of different gases contain equal numbers of molecules. It doesn't matter if you have argon, which is by itself atomic, or we have oxygen, which is diatomic, or you have methane, which is CH4, five atoms making a compound. Equal pressure, equal volume, equal numbers of those species. So that was Avogadro's Law.

So let's put that down. At constant pressure equal volumes of different gases, contain identical numbers of atoms. Equal volumes of different gases contain equal numbers of molecules. And here I'm using the term molecule as a counting unit. So it could be, strictly speaking, an atom or it could be diatomic and so on. That's what it was. And out of honor for Avogadro, we name the number of atoms in the mole the Avogadro number. Which I've written

6.02 times 10 to the 23rd.

Now how do we determine Avogadro's number? That's an interesting story. So first of all, we need two pieces of information. Because we're going to do this by the noblest form of chemistry, electrochemistry. So the first thing we're going to do is we're going to look at the work Michael Faraday in England. And what Michael Faraday did is he studied the electrodeposition of metal. And specifically he passed current through a cell and he electrodeposited silver. So he starts with silver plus, that's silver a cation, and by the action of electric current attaches an electron to silver and renders it neutral. Silver, which now plates out onto an electrode and they measured the mass. They measured the mass of silver-plated and they compare it to the amount of charge that was passed. They measured the charge.

And you can get charge, because you know current. So charge is simply equal to the integral of the current times the time. You know the current, that's easy. And what Faraday found was that to make what we now know to be 108 grams of silver, 108 grams of silver, which we're going to subsequently recognize as the mole, which is identical to the amount, the number of particles in 108 grams of silver, is equal to the number of particles in 12 grams of carbon. Sort of an Avogadro-type harkening. He found that that is-- the equivalent requires 96,485 Coulombs. So you can say 1 mole of electrons gives me 1 mole of silver, so that's the charge on 1 mole of electrons, where Coulomb is the elementary charge, because we know 1 electron per 1 silver atom deposited.

So now if I know that's a mole of electrons, I need to find a charge on one electron, divide through and I get the Avogadro number. And to finish the story we have to wait about 50 years and come to the United States, where it's Robert Millikan, Robert Millikan at the University of Chicago doing the oil drop experiment through which we learn the elementary charge.

And here's the cartoon of the oil drop experiment. I took this from a different text. It's not shown in your text. So I actually did this experiment as a sophomore at the University of Toronto. They had us repeat some of the great experiments of physics, the ones that were accessible, obviously. I couldn't do high-energy physics in an afternoon. That would have taken me a little bit longer. But we did this one.

And so it consists of an atomizer, sort of a perfume atomizer, in which there's oil. And by the action of atomization we form a shower here, a very, very fine dispersion of tiny droplets of oil. And then-- this cartoon is hard to make sense of so I fixed this-- we shine high-energy radiation on this. And by the action of high energy radiation we take these neutral droplets and we turn them into ions. We eject electrons. And so now these are charged. And then we charge the plates. So if we have neutral species and they simply come out of the atomizer, they'll settle under gravity. But now if they're charged and I put a charge on the plates-- let's say as here the upper plate is positive-- if any of these particles is charged positive, the action of the electric field will accelerate the descent, because the bottom plate is negative attracting and a positive plate at the top is repelling. And vice versa. If I have a particle that's negative, the upper positive plate will actually cause it to slow down, and in the extreme, it may actually start to rise.

And so what Millikan did is a set of experiments in which he studied all the different particle sizes. See this telescope? Right over here is Millikan. And Millikan's sitting there and he's squirting and he's watching. He's measuring the settling velocity. And he changes the magnitude of the electric field. He changes the intensity of radiation. He changes the nozzle. He changes everything he can. And what does he find? He finds that the distribution of velocities is not continuous. It's not continuous. You think, well, gee if you just keep dialing you should get every variation of velocity. Well, he doesn't. He finds that he gets variation down to a single value, below which he can't go. He determines that electric charge is quantized. That is to say there's a base unit. It's an element.

I just talked to you about the elemental building block. That's an element in mass space. Now I'm going to go conceptually into charge space. There is an elemental building block of electric charge. Electric charge is quantized. And he found that the elementary charge, which we gave the symbol, e. e is not the symbol for electron. e is the symbol for elementary charge. It has a value, if you convert it to modern SI units, of 1.6 times 10 to the minus 19 Coulombs. So now I can take these two pieces of information, Faraday which is up here. This is known as the Faraday Constant. Script f, Faraday constant.

So if I divide the Faraday constant, which is the charge on a mole of electrons, by the elementary charge, which is the charge on one electron, presumably I should end up with the Avogadro number. It should be the ratio of the Faraday to the elementary charge. And it gives us-- for the third time this morning-- 6.02 times 10 to the 23rd. If you like per mole, yes or no, doesn't matter. So now, what's the atomic mass unit? Now we can say the atomic mass unit is, 1 atomic mass unit then must equal what? It's going to equal 1/12 of the mass of carbon 12. 1/12 of the mass of carbon 12 divided by the Avogadro number, which gives us 1.661 times 10 to the minus 27 kilograms.

Now be careful because the system is just a little bit rickety. You know we went SI, but look, this is still defined as 12 grams. And so sometimes if you look depending on where this is, 10 to minus 27 kilograms or 10 to the minus 24 grams. Just be careful. If you ignore this you'll be off only by factor of 1,000. That's a joke. But it's lost here. People are too serious. We'll lighten you up.

All right, so enough of the history. Let's now do something dynamic. So far we've been studying static elements. But chemistry is really the action of elements in motion. So how do we describe a chemical reaction? Let's look at that. What are the rules to describe a chemical reaction? Write an equation. Write the equation of the chemical reaction subject to these rules. There are two simple rules. One is conservation of mass. We've been told the repeatedly since Democritus, conservation of mass. And the second thing, we use Dalton's Law of Molar Proportions. That is to say, the building blocks in integer ratios.

And so I thought I'd do this in context. So I've got a specific example here. So this is something that I'm interested in. Some of my research is in metallurgical extraction by benign processes. What you're looking at is a billet of titanium. To give you a sense, you can see the stairwell back here. So this is about 4 feet, a little over a meter here. So you can see this is one honking big piece of titanium. This came out of the primary reactor, the Kroll reactor and this is subsequently swaged and hot worked and so on to form these billets.

So this is the first step of turning dirt into metal. That's called titanium sponge. And titanium sponge occurs inside a Kroll reactor. It occurs inside a Kroll reactor, which was invented by a man of the surname Kroll in Luxembourg in the 1930s. And then with the advent of World War II, he decided to be smart, to get out. And he ended up in Oregon where he became a professor. So he's known as Professor Kroll, although the truth be told he really made his discovery before he became a professor. But he's still a professor and so we'll honor him. And so the Kroll process for making titanium centers around this reaction.

Here's the reaction written according to the rules above. We take titanium dioxide, which is found in the Earth and by some prior chemistry convert it to titanium tetrachloride, and in a reactor that I'm going to show you in a moment, we react titanium tetrachloride with magnesium. And magnesium has a higher affinity for chlorine than does titanium and steals the chlorine from titanium to form magnesium chloride, leaving behind titanium metal.

Now we have to have conservation of mass. So you can see, I've got 4 chlorines on the left but only 2 chlorines on the right. So I'm going to put a 2 here and double the magnesium chloride. But now I've got 2 magnesiums on the right and only 1 on the left. So I'll put a 2 in front of the magnesium and now we have a balanced equation.

And here's what the reactor looks like. You can imagine a giant vessel with a pressure seal on the top and a couple of valves, big enough to make this. So this is about 15 feet by 30 feet. And so we introduce titanium tetrachloride, which is a gas, and magnesium as a solid and heat to 900 degrees C. And at 900 degrees C, if you look on your Periodic Table you'll know that magnesium melts at 650 degrees C. So we have a liquid sitting here, titanium tetrachloride here, and this thing is sealed. It's called a bomb reactor. Nothing can get in, nothing can get out. The pressure builds up here. And right at this interface the titanium tetrachloride reacts with the magnesium according to this reaction.

Now this is very interesting. It's beautiful reaction because the titanium tetrachloride is a gas; magnesium is a liquid. Magnesium chloride is a liquid, but it is of different density, and it is insoluble in magnesium, and titanium melts at 1670 and it's a solid. So what happens over time is this. The magnesium chloride that forms pools underneath the magnesium liquid, gets out of the way so that we can continue to keep this interface clean and have the reaction proceed. You don't want to reaction where reactant A reacts with reactant B, makes a product that covers the interface and now the product is in the way of future reaction.

So this is very elegant because I don't need any fans, I don't need any nose propellers, nothing. By density the magnesium chloride settles and the titanium settles. And it's sitting here at the bottom. And you can imagine if we do this long enough, this titanium at the bottom will continue to build until it looks like this. As long as you keep feeding TiCl and Mg. See I'm talking metallurgy now. TiCl and Mg, that's what you make. So that's how we make titanium, first step.

And so suppose you get hired and it's your first day on the job and you're working at Cambridge Titanium and the boss says let's put in 200 kilograms of TiCl and we'll put in 25 kilograms of Mg. And the question is, what is the yield? What is the yield? How much titanium are we going to make? Well, you say, just multiply it out. But first you have to see if things are in balance. We have to study the stoichiometry of the reaction. Stoichiometry, what does this mean? It's from the Greek, stoicheia, which has to do with measurement proportions.

So if these are not put in to the reactor in proportion to what they are in the equation we're not going to get the yield here. So first thing I gotta do, this is in moles, this is in kilograms. So I have to convert the kilograms to moles and then maybe I can make some sense of this. So if I divide by the atomic mass of titanium, four times the atomic mass of chlorine and convert; I will discover that I have 1,054 moles of TiCl. And I've got about 1,029 moles of magnesium. Well, this equation says I need 2 times the amount of titanium tetrachloride. Well, it's obvious to the naked eye, 1,029 isn't two times 1,054.

So I've got a problem here. I'm not going to get as much titanium as I put in. Titanium chloride. This yield is going to be restricted. It's going to be restricted by-- this is sort of a chain is as strong as its weakest link-- the yield is restricted by the amount of limiting reagent. And in this case, magnesium is-- this is less than 2 times the mole number of titanium chloride. So this means this is the limiting reagent.

Alright so now if we use that principle then I'm only going to get as much titanium as I had magnesium and you can see from the stoichiometry here, if I've got 1,029 moles of magnesium I'm going to have half of that number of titanium. So therefore the amount of titanium is equal to 515 moles of titanium. And you notice I'm not obsessed about a significant figures and so on. It's a metallurgical plant. Half of 1,029 is 515. Is it 514.5? If you wish. I don't care. So 515 moles and then I convert that, which gives me 24.7 kilograms of titanium when I use that amount of magnesium.

And if you go to the text, Section 2.7, you'll see the nuts and bolts of how to run these reactions. For those of you who had a lot of chemistry in high school, I know this is review, but I want to bring everybody up to the same page. So we're starting with this.

All right. I think that's a pretty good place to stop with the delivery. But I don't want you moving. You don't move yet. Because the last 5 minutes I'm going to still continue to talk. But on a slightly different topic. And so I don't want to hear the binders snapping and so on. We're here; you paid your money. Five more minutes. Five more minutes and then you're out there. Out there, then begins le weekend. But not until then.

So a couple of things. First is, the music today. I try to link the music thematically. So the music playing today was Polovstian Dance number 17 from Prince Igor, by Borodin, Aleksandr Borodin. Why were we listening to this music? Well, because I insisted that we listen to it. Well, what about Borodin? Borodin lived in Saint Petersburg. He was a friend of Mendeleyev. OK, that's cute but more importantly Borodin wrote his music in his leisure time. He had a day job. His day job was professor of chemistry. And he worked at the Medical Surgical Academy in Saint Petersburg. He was an exceptional human being.

In those days, women were forbidden to attend institutions of higher education. He set up an entire curriculum for women in a night school at the Medical Surgical Academy. He cavorted with artists and therefore obviously his politics were radical. And they were trying to reform the political scene in Czarist Russia at the time. And he was also quite a bon vivant. And he died on his feet dancing at a ball. So that's the way to go. Having a great time. That was Borodin.

One other thing before you go. You were very very dour, so I thought I'd try to put you in a good mood to the extent this is possible with this group. And I wanted to share with you some news. There's been a new element discovered. You know these atoms smashers, they're always working. And so the discovery of the heaviest element known to science has been reported. The element, tentatively named administratium. I don't know if UPEC is going to go for this, but you can suggest names. So they're going to name is administratium, the discoverers. It has no protons or electrons. So that means its atomic number is 0. It does have one neutron, 125 assistants to the neutron. 75 vice-neutrons and a 111 assistants to the vice-neutrons. This gives it a mass number of 312.

The 312 particles are held together in the nucleus by a force that involves the continuous exchange of meson-like particles called memo-ons. There's no electronic mail, because there's no electrons. There may be neutronic mail but we don't know yet. Now you've already learned something today. You know something. Since it has no electrons, what do we know about its chemical reactivity? It's inert. It has no electrons. It can't exchange. So this is chemically inert. So you say, how did they detect it? Because it seems to impede every reaction in which it is a present. According to the discoverers a few nanograms rendered a reaction that normally takes a fraction of a second, it took now four business days to conduct that same.

There are a few other properties. We know so far that it's radioactive. And we're going to study radioactivity later, so there's a little bit of foreshadowing. It has a half-life of about three years, at which time it stops decaying and instead it undergoes a reorganization, in which the vice-neutrons, assistants to the neutrons and assistants to the vice-neutrons, exchange places. Some studies indicate that the mass actually increases after each reorganization. So you can imagine now we'll have something like this. See how this increased? So if they occupy the same place, they have the same proton number, but a different neutron number, in the case of administratium, they're called isodopes. So with that I will say, have a good weekend.