Science AMA Series: I'm Dawn Shaughnessy, from the Heavy Element Group at Lawrence Livermore National Laboratory; I synthesize superheavy elements, and I helped put 6 elements on the periodic table so

DAWN_SHAUGHNESSY R/SCIENCE

Hello, Reddit. I'm Dawn Shaughnessy, principal investigator for the Heavy Element Group at Lawrence Livermore National Laboratory. Just last week, our group was credited with the discovery of elements 115, 117 and 118 by the International Union of Pure and Applied Chemistry (IUPAC).

This discovery brings the total to six new elements reported by the Dubna-Livermore team (113, 114, 115, 116, 117, and 118, the heaviest element to date), all of which we synthesized as part of a collaboration with the Joint Institute for Nuclear Research in Dubna, Russia, and Oak Ridge National Laboratory in Tennessee. One of those elements, 116, was actually named Livermorium, after our laboratory and the California town we're in.

Anyways, I'd love to answer any questions you have about how we create superheavy elements, why we create them, and anything else that's on your mind. Ask me anything!

Here's an NPR story about our recent discovery: http://www.npr.org/sections/thetwo-way/2016/01/04/461904077/4-new-elements-are-added-to-the-periodic-table

Here's my bio: https://pls.llnl.gov/people/staff-bios/nacs/shaughnessy-d

I'll be back at 1 pm EST (10 am PST, 6 pm UTC) to answer your questions, Ask Me Anything!

UPDATE: HI I AM HERE GREAT TO SEE SO MANY QUESTIONS

UPDATE: THANKS FOR ALL OF THE GREAT QUESTIONS! THIS WAS A GREAT AMA!

Given that we end up with atoms that exist for fractions of a second, what can we say about the properties of the new elements?

doc_frankenfurter

In order to say anything about the chemistry of these elements, we would have to be able to produce them and isolate them before they decay. As we go to heavier and heavier elements, their lifetimes are becoming shorter, which makes chemistry extremely difficult. We are thinking about ways to perform chemistry on some of the lighter heavy elements that haven't been studied yet, but performing chemistry on element 117 or 118 would be very difficult based on their sub second lifetimes. All we can say for now is that based on their position in the periodic table based on their atomic numbers, we can predict that they might behave similarly to the other elements in their respective groups (columns) of the periodic table.

How close are we to reaching the island of stability? Also is element 118 going to be considered a noble gas (and end in - on)?
Sabodis

Hi Sabodis The Island of Stability will be reached when both the number of protons and neutrons are in a full shell (extra stable) configuration. While the next "magic" number of protons is predicted to be 114, 120 or 126, we are still too far away from the next extra stable configuration of neutrons. If we are ever able to get more neutrons into these elements, we will be closer to the Island of Stability

When your job is discovering new elements, what's a typical day at work?

PaulsRedditUsername

Each day varies. Our group works on a variety of nuclear science and radiochemistry projects so we might be in the laboratory working on a new chemical separation, or we may be at the accelerator or doing research at the National Ignition Facility (The largest laser in the world lasers.llnl.gov). We have many interesting projects we are working on so one thing for sure is our days are not boring!

How close are we (humans) to synthesizing element 119 (Ununennium)?

StormCrow1770

There are groups that are already thinking about how to synthesize even heavier elements such as 119 and 120. It is becoming more difficult because the probability of elements fusing together to make a superheavy element gets smaller and smaller the higher we go. We also need to think of new reactions to use to get there, which includes research into new particle beams and targets. So researchers are working on it, but it may take a while.

What's the coolest piece of equipment you get to work with?

vandezuma

We are very fortunate to collaborate with the Flerov Lab for Nuclear Reactions in Dubna, Russia. They have one of the most intense cyclotrons (particle accelerator) in the world. It is a large piece of machinery that accelerates ions to very high velocity and then bombards them into a target so that we can attempt to create a new element. Without this piece of equipment, these experiments would not be possible.

1. Is there any computersimulation, quantum mechanical simulation done when it comes to predicting stabilities or properties? (if its even possible)

2. What was the biggest suprise you had regarding the new elements you created?

question__010

There are theorists that do work in simulations of what the next closed nuclear shells will be. That is how we know that the next closed proton shell will be either at 114 or 120, or even 126. The next neutron shell is predicted to be at 184 neutrons. The simulations have driven the experiments.

One of the biggest surprises is just how sensitive the technology has become to detecting a single atom of a new element with an extremely short half-life. These experiments were not possible many years ago; the technology in electronics and detectors have made this possible.
What makes element 119 significantly harder to synthesize than the other recent superheavies?

Do you think we will ever reach the so-called “Feynmanium” where atomic physics breaks down, or do you think nuclear instability will be too big a factor?

As we go up in atomic number, the probability that we can fuse two lighter elements together to create a superheavy element gets smaller and smaller. There are two nuclear forces at work - the repulsive force between the protons that wants to rip the nucleus apart, and the strong nuclear force, that holds the protons and neutrons together. At some point, the repulsive force wins out and these elements have a very low probability of being formed. Each time we go up in number, the odds that one can be produced get very small. We also have to have the right combination of beam and target materials to fuse together.

Are you done now that row 7 has been filled or are you going for even heavier elements? If so, what is your next target?

There are plans in the community to study the chemistry of some of the lighter heavy elements that have not been studied yet as well as to pursue creation of even heavier elements. I am personally very interested in the chemistry of these elements so our current work focuses on methods for automated chemistry development, but the community is also thinking of ways to create new elements as well.

How much material can you make of the most stable heavy elements? Any chance of investigating the chemistry of these elements? What measurements can be done?

A typical experiment lasts several months and in a successful campaign we might observe 1-3 atoms over that time. The chemistry of some of the lighter superheavies has been studied, but those elements live much longer than the ones we are talking about here. The community is trying to push chemical studies down to the seconds time frame using gas-phase methods. It will be very difficult to push down to the subsecond regime with chemistry, but of course that would be an ideal way to determine the position of these elements in the periodic table.

In your day-to-day how much time is spent on the theoretical side vs. the practical side? Basically, do you spend more time with a whiteboard or in the lab?

We spend time with both. The theory drives the experiments. Since these are long experiments, they are scheduled for a set amount of beam time that may last several months. Then there is an equal amount of time spent analyzing the huge data set that is generated and evaluating the results.

Which was the easiest, of the 6 elements that you made, to produce?
Easy is a relative term here as these are all difficult experiments, but in general the even numbered elements are “easier” to make detect because their decay behaves very regularly and we can predict what their lifetimes and decay energies might be. The odd numbered elements are more difficult to detect because their decay can go several different ways and we have to sort out whether we are seeing different decays from the same element or different elements.

Has anyone ever proposed a practical use for superheavy elements in some kind of machine or process? Presuming there never has been any potential application for the elements, can you describe the motivation for expending the effort to try to generate increasingly heavy nuclei? What new principles or science is learned from these projects?

shiningPate

The interest in discovering new elements is to refine our theories about the existence of matter and how the nucleus is formed. The theories on how the nucleus is configured have changed quite a bit over the past decades. Every time we push the boundary of finding a new element, it helps to refine these models and our basic understanding of the extreme limits of matter.

Are there computational methods for calculating the the stabilities of the nucleus? How accurate are they? Do you still utilize the nuclear shell model?

nallen

Yes indeed, they are still using the nuclear shell model to calculate where the island of stability might be located. We have observed effects from the island of stability around element 114, but we are still a ways off in neutron number. The theories have predicted either element 114 or 120 for the next closed proton shell, and 184 for the next closed neutron shell. So the theories are probably pretty close, but we can't quite get there because we are too deficient in neutrons.

How exactly do you go about chemically synthesizing these heavy elements? And how do you measure them when they only exist for such a brief period of time? Congratulations on your accomplishments!

buhbuhbweee

A new element is created by fusing two lighter elements together. We basically use a reaction where the total proton number is the sum of the protons in the beam and target nuclei. Using a cyclotron, a beam of particles is accelerated to very high velocity and blasted into a target. The reaction products are emitted from the target through conservation of momentum and they travel through a separator. The separator consists of large magnets that allow the heavy elements to travel through while the lighter beam particles are removed. After traveling through the separator, the heavy element is embedded in a silicon detector where we observe its nuclear decay. We don't see the actual element because it is too short-lived but we do see its radioactive decay particles and can then link those back to the original element we created.

Hello! I was very excited to see the IUPAC news confirming 113, 115, 117, and 118. I was wondering how the collaboration comes to a naming decision when there are so many teams involved—is there a ‘vote’ of some sort or will the lab heads get to make the final call, or something else? Any contenders so far?! Thanks a lot!
I can only comment on the last time we went through an element naming - in that case it was
discussed at length between the US and Russian groups until consensus was reached. It is supposed
to be decided by the members of the research team that are credited with the discovery.

Is your group near discovering or stabilising new elements, if so which ones?

Do you think any of this last elements (113, 114, 115, 116, 117 and 118) are gonna have any good
impact for the future and any kind of use for them?

SirJoker97

It is getting more difficult to go up in atomic number because the probability of these nuclei holding
 together for long enough for us to detect them is getting smaller and smaller. We also need to look into
 alternate reactions for creating them, such as new beam and target materials. So we are still pushing
 for new discoveries, but there is research to be done in how to accomplish them.

When did you decide that you wanted to be a scientist?

fistingfish

When I was in middle school I started to really enjoy science and thought that being a scientist would
be a really interesting and exciting career. It was in high school when I decided that chemistry was the
particular field I wanted to go into.

How stable are the new elements? Is there any practical method to produce specific isotopes which
may be more or less stable?

newguynewguynewguynewguy

The new elements only exist for a fraction of a second. In order to get more stable isotopes, we would
need to use more neutron rich target and beam particles.

What is the single most amazing thing you’ve ever witnessed in the lab?

redstert

I also work on the National Ignition Facility (lasers.llnl.gov) and seeing the world's largest laser work is
really an amazing feat. Seeing NIF and watching it work have been truly amazing.

The field of physics is well-known for its very high statistical significance requirements. Approximately
how many syntheses of a heavy element are required to achieve this level of certainty? How long does
a single synthesis take?

shiruken

A typical experiment lasts several months and anywhere from 1-3 atoms might be produced in that
time if we are successful. If the new elements decay to previously known elements, then we are more
certain as to their identity. Usually the experiments are repeated or performed at different energies to
verify the results. So there are usually a handful of atoms that are produced of any given element.

Thanks for taking the time to do this! I've got an MS in Analytical Chemistry, yet nuclear synthesis has always interested me.

Do 117 and 118 show any signs of exhibiting behavior like those of halogens and noble gases, respectively; or is the atom count still too few to determine these chemical properties?

Do you believe that the upcoming magic number observed in neutron count of 126 will impact a potential element Z=126?

What special precautions would have to be taken before synthesizing Z=119, as it may be water reactive and pyrophoric if it follows the trend of alkali metals.

Do you believe that SPDF are the only four sections of the periodic table, or the super-heavy elements may reveal something beyond the F-block? What would you think the implications would be of another set of electron orbitals?

You are right - there are too few atoms made of these new elements to really determine their chemical properties. When we do chemistry on the lighter heavy elements, we usually do chemistry literally on a single atom at a time and then extrapolate the results based on the results compared to their neighboring elements in the periodic table. These new elements are so short lived that chemistry will be very difficult unless longer lived isotopes are found.

Another question and a followup about the island of stability hypothesis.

- Assuming the island of stability is a reality, are there natural events (supernovae or anything else) that might create elements in the island? Can you elaborate on any you feel are promising?

- Do you have any hypotheses about how we might detect such elements in nature, and whether any tests of this sort might have merit as methods to test the island of stability hypothesis?

Theoretically, a supernovae would produce heavy elements, but they would decay right afterward. There have been searches for superheavy elements in nature, but they did not result in any positive results. These elements are just too short-lived to detect. Originally, people thought they might live for many years, which is why it was thought there might be some in nature.

Thanks for doing the AMA Dawn!

1. What do you think about theoretical limits to 'making' elements, like super-heavies?

2. I'm a chemist, though admittedly in the pharmaceutical industry, but I have to ask, what's the purpose of synthetic elements that only last fractions of a second? Is it simply to understand the physics behind it all?

The limits to making new elements depend on the availability of target and beam materials that can be fused together to make a new element, and the ability of the nucleus to hold itself together long
enough for us to be able to detect it. As lifetimes get shorter, it will be harder to "see" a new element even if we technically produce one. It is getting more difficult to make new elements, so we may reach the technical limits of what we can do first.

What are the current projections vis-a-vis the time it would take to synthesize elements from the island of stability?

Are there concerted efforts to do so?

What are their likely uses?

dicefirst

In order to reach the true island of stability we need to push out in neutron number. We currently don't have combinations of target and beam that we can use with high efficiency to reach the 184 neutrons we need. Researchers are looking into ways to use new beams as well as radioactive beams, but they are still a ways off from getting to the center of the island of stability.

Are you ever able to test the specific properties of newly created elements? Things like conductivity and heat transfer, if the latter is an atomic property in the first place.

Can these things be figured out with just theory?

UnknownEngineer

Studies are done on single atoms and then usually inferred by comparing their behavior to those of the bulk properties of the neighboring elements. Theory tells us that if we go down a chemical group (column) in the periodic table, the chemistry of those elements should behave in a similar fashion. Theorists are indeed looking into how the chemistry of these elements might differ from the rest of their chemical group due to their massive size (so called relativistic effects).

What degree/college courses would I need to take to have a career like yours? thanks :)

theflyingbrant

I majored in chemistry in college, which also included courses in physics and math. I then went to graduate school in the field of nuclear chemistry. So basically, learning about physics and chemistry would be a great start.

What is the major factor determining how difficult it is to synthesize particular element? Does it mostly depend on total nucleus mass, its charge, electron cloud configuration, stability/lifetime?

catnipd

The major issue is being able to find a combination of beam and target that will give us the right numbers of protons and neutrons. We need enough energy to be able to overcome the repulsive force between the protons that is trying to drive the nucleus apart, which is why we use a particle accelerator.

What did you want to be as a kid? I ask because you are kind of a superhero pushing all of mind kind
forward and kids should grow up wanting to do cool things like this more!

hypercube33

At first I thought I might want to be a doctor or surgeon, but then I got really interested in science in middle school. In high school I realized that I wanted to be a chemist. I do try and encourage kids to learn science because I think that too few are getting the opportunity to learn about the world around them.

I wish I had a better question for you but I just woke up. Are any of these metals more stable in different conditions, like a vacuum? Or do they decay at the same rate regardless of the environmental conditions? Thanks for the AMA!

lildil37

These elements are so short lived that they decay before they can really interact with their environment.

Hey thanks for doing this, tbh most of your work is beyond my knowledge but still amazes ame to read about it. My question is, how do you feel knowing that what you did is a part of history now? I find it amazing people that actually make a dent at least on our future like you did.

Thanks

weedy2

I am very proud to have had a part in these projects. The science still amazes me and I am very humbled and proud to be part of this. I hope we can encourage the younger generation to look into science and be curious about the world around them.

I have always wondered what pieces of machinery were used to synthesise and identify the super-heavy elements? Also how difficult the techniques are to use?

jamster009

We use a particle accelerator (a cyclotron) to accelerate light ions to very high velocities and then slam those into a target. There is enough energy in the system where the two nuclei can fuse together and combine all of their protons and neutrons into one nucleus. Through conservation of momentum, the new nucleus is ejected out of the target and we use a magnetic separator to transport the new nucleus away from interfering particles to a detector. The nucleus is implanted in a silicon detector and we observe its radioactive decay. We register the electronic signals from these decays and then use large computers to sort through the data and look for events that we can link to a new heavy element.

I very doubt that a practical application is feasable, even because we're talking about very small amount of material obtained with these trials. Are there any techniques available to obtain, in case we'll reach the island of stability sooner or later, to produce adequate quantities for material studies?

drpbrock

These atoms are produced one at a time because the probability of making them is very small. Unless we found isotopes that are longer lived, we would not be able to have enough of them at once to do a
real material study. Chemical properties of the longer lived heavy elements are done with single atoms, and their behavior is inferred from those observations and compared to their neighboring elements in the periodic table.

If there is an Island of stability, what are the chances that elements inside it can/will be discovered via exhaustive mass spectrometry rather than collision? That is working backward from the assumption of stability: if they are stable and can exist, then they may already exist in nature in extremely low quantities, therefore we will use some sort of highly parallel mass spec. looking at single atoms to sort through say... $10^{10}$ atoms looking for ones that are heavier than known atoms.

Lucretius

There have been searches for heavy elements in nature using mass spectrometry. There have been some published papers on that just in the last year.

Recognizing it may decay relatively quickly, what's the heaviest naturally occurring element?

cv5cv6

Uranium is the heaviest naturally occurring element.

What's your favourite form of the table? Mendeleev's is nice and logical, but there are spirally ones and spiderwebby ones.

logicalmaniak

I personally like the current one with the rows and columns. It helps me visualize the theoretical chemistry of these elements.