

## But Why: A Podcast for Curious Kids

### Why Are Fireworks Bright?

July 2, 2021

**Jane** 00:21

This is But Why: a Podcast for Curious Kids from Vermont Public Radio. I'm Jane Lindholm. On this podcast, we follow your curiosity. You send us questions and we track down the answers. And right now you're taking us too bright lights and loud noises and cultural celebrations that happened around this time of year in the United States. Does this sound familiar at all? Without a visual clue, it might be a little hard to figure out. But that's the sound of fireworks. Many of you are curious about how these celebratory explosions work and why we use them. Historians and archaeologists think fireworks started in China maybe as early as 2,200 years ago. And they've been used in Europe and other parts of the world for at least 800 years. In the United States, where our show is based. They've become a big tradition on the Fourth of July.

**Nicholas** 01:17

So hi, my name is Nicholas, and I'm six years old. I live in Plymouth, Michigan. And I want to know why people do fireworks on the Fourth of July? Thank you. Bye.

**Jane** 01:33

Well, Nicholas, Americans have been celebrating July 4 with fireworks since 1777, the first anniversary of the signing of the Declaration of Independence. John Adams was one of the people who signed that document in 1776 a year earlier, declaring their wish for the American colonies to become independent from England. Afterwards, Adams wrote to his wife that he wanted that day to be celebrated with lots of parades, shows, bonfires, bells and illuminations.

**Jane** 02:04

Adams was a well known person in the early days of the United States. He later became the first vice president and the second president. So his wish would have been shared with others as well. And so on the one year anniversary of the signing, the city of Philadelphia had a big celebration with 13 fireworks, one for each of the original 13 colonies. Now, John Adams didn't come up with this idea entirely on his own English royalty had been using fireworks for national celebrations since at least the 13th century, which is when fireworks came to Europe. They were widely in use by the 15th century, that's about 600 years ago, but they were hard to find in the early days of the United States, so celebrations back then often included guns and cannons more than actual fireworks. Fireworks became more common in the 1800s. And by then the Fourth of July was regularly celebrated. It became a national holiday in 1870.

**Jane** 03:02

Fireworks aren't just popular in the US. Of course, other countries like Canada, Australia and Singapore celebrate national holidays with fireworks. The Festival of Lights known as Diwali, celebrated in India and all over the world has lots of fireworks. And in the United Kingdom, Guy Fawkes Day often concludes with big bonfires and fireworks. And lots of cities and towns all over the world set up fireworks to mark the transition from one year to the next on New Year's. Sometimes communities, festivals, sports teams have fireworks just because for fun.

**Jane** 03:39

Lots of you want to know more about what fireworks are and how they actually work. So let's jump right in. Today we've got two experts in pyrotechnics. That's the art and science of making fireworks. Here's one of them.

**John** 03:53

I'm Dr. John Steinberg.

**Jane** 03:55

In his regular job, Dr. Steinberg is a physician, a doctor who sees patients but he got interested in fireworks when he was a kid.

**John** 04:03

And I started doing experiments in pyrotechnics, firework chemistry, when I was 10 years old, you know the backyard magic shows and how to make collars and how to color flames.

**Jane** 04:14

And when he was an adult, he got trained and certified in creating and setting off the kinds of fireworks displays you might have seen in a city or on TV. Our other guests today David Chavez is an energetic materials scientist, an explosives expert, at the Los Alamos National Laboratory in New Mexico.

**David** 04:33

The scientists that I work with, they grew up really loving fireworks and explosions and things like that they would take apart, you know, the things they would buy and try to learn how they work, but they were made of I was not that kid at all.

**Jane** 04:48

David says he was more interested in astronomy and generally in math and science. But he got an amazing opportunity to work with the scientists at Los Alamos when he was in high school.

**David** 04:59

It was in a program by the American Chemical Society called Project Seed. And so it was a program for students that were maybe in the like socio-economic disadvantage kind of categories, which I was one. And so I had this opportunity to go from a very rural, non-science kind of community into the laboratory and just explore what science and engineering was all about. And that really piqued my interest and really wanting to follow a career and in the sciences.

**Jane** 05:32

And the scientists you worked with, were doing pyrotechnics. So that's the direction he went. Since then, he's done some amazing things that we'll learn about later in the episode to help make fireworks more environmentally friendly. Now that we know a little bit about our guests, John Steinberg and David Chavez, let's get to your explosive questions.

**Leila** 05:53

My name is Leila. I am 7 years old. I'm from Flagstaff, Arizona. And my question is, what are fireworks made of?

**Jane** 06:04

To put it simply John Steinberg says every firework has three components.

**John** 06:09

One, they have to have a way to get in the sky. And that's done with black powder, gunpowder, the same as in uses in black powder, firearms, black powder blasting, there's a little bag of gunpowder, which is another name for black powder. And that pushes the firework into the sky, and lights a fuse that goes into the firework. The second of the three components is something's got to hold it all together, it travels up in the air and then performs where you want it. And that's the shell casing. And the casing for the shell is made of cardboard paper mache. But inside the guts of the firework the contents, when it goes up in the air, what effect do you want? Do you want a ball? Do you want colors? Do you want a smiley face, you want to shape. You want things that whistle and spin and you see streamers coming out with silver sparks and things that make noise. So those are the three components fireworks are made of something to get it into the air, gunpowder, a casing hold it all together paper mache or cardboard. And the stuff inside the firework, which like every other fire is things that provide the oxygen and things that get burned. It's a kind of a special fire in the air. And that's the effect you see in the sky.

**Jane** 07:33

So what are the things that make those colors in the sky?

**David** 07:36

Typically, the coloring agents are metals like sodium, potassium, calcium, but you can have heavier metals like barium, strontium, and copper as well is another is another metal.

**Danika** 07:50

My name is Danika. I'm five years old, and I live in Atlanta. And my question is how are fireworks made. Thank you. I asked this question because it's July 4.

**Jane** 08:08

Danika wants to know how fireworks are made. So you've talked a little bit about what they're made of. But you mentioned that there are so many different kinds of fireworks and you can make ones that are different colors that do different kinds of explosions in the sky that make different noises. So how in the world do you put all of that into one little cardboard-covered vessel?

**John 08:31**

Well, there are all kinds of fireworks. But let's talk about making an aerial shell, the ball that goes up in the air and goes bang and puts the colors in the sky. First, you have to have the chemicals to mix and make your formulas. So for instance, if you want red dots in the sky, we would need something that produces the red color, something to burn, and something that supplies the oxygen. So when you learn chemistry, you know how to make the equations and the formulas to figure out the recipe like baking a cake, what amount of this and what amount of that. And then you mix the chemicals. And typically you moisten them with either water or something other than water so that you can form the little pellets. We call them stars.

**Jane 09:19**

Then you dry the stars out again and arrange them into a ball that's filled with other things that can burn so they explode at the right height and make the right pattern. You also need to include material that will burn inside the firework so you can set those stars on fire in the first place. You coat the whole firework with a kind of paper mache to hold it together. And then you also need a fuse a special kind of string that you can light at one end that will burn into the firework as it's shooting up into the air. So it explodes at the right time way high up. Remember what David Chavez told us? Those stars, the part of the firework that lights up in beautiful colors and patterns in the sky. Those stars are made with various metal that burn in different colors. So here's something cool to impress your friends and family with, you can tell them what metal is being used in the firework you're watching, just by noting the color.

**David 10:12**

Anytime you see a red firework, that's always going to be strontium. But if you see something that's kind of like pinkish purple, then that's more likely to be potassium salt. Yellow is from sodium. So like, you can even add table salt as a metal to a firework. Orange tends to come from calcium. The green is from barium or now you can also use boron, and blues are from copper, and then the color combinations that you get like if you were to mix to make something that's a little bit more purple. So you would be mixing a little bit of strontium and a little bit of copper in your firework. And so the blue and the red would mix and they would make a little bit more like of a purple ish color.

**Jane 11:03**

Is there any color that still can't be made?

**David 11:06**

Completely pure blue color is pretty elusive. And so copper tends to get close. But it's not pure blue color. There are some better metals, but they're pretty toxic.

**Jane 11:20**

David says people are still doing research to figure out how to make a firework that is both beautiful, pure blue, and safe. Maybe you'll be one of the people who figure that out.

**Rebecca 11:31**

Hi, my name is Rebecca. And I five years old., I'm from London, England. My question is how do fireworks set off.

**David 11:44**

Your three primary ways to set off fireworks, to perform a display. The first is the hand fire show, still a staple of firework shows around the world. You light the fuse, we use a railroad flare or a fuse, or a torch or something in a holder. And a person a manual operator actually pulls off the protective cap and lights the end of the fuse and puts it in the air.

**Jane 12:12**

By puts it in the air John means uses a device that fires it into the air not like people throw it up into the air themselves or anything like that. But basically, it's a person determining when to shoot that firework into the air and set the whole thing in motion.

**John 12:27**

But you're limited in terms of how big the shelves can be. The rules in the United States say the biggest show you can light by hand is a six inch shell.

**Jane 12:36**

And a six inch shell you could hold if you were a kid, you could you'd probably hold it in two hands.

**John 12:41**

Correct. It weighs about four or five pounds. But we use eight inch shells and 10 inch diameter shells and 12 inch diameter shells. And at the Pyrotechnics Guild International, we have launched shells of 24 inch diameter and 36 inch diameter.

**Jane 12:58**

That's a really big ball. To give you an idea. Basketball has a diameter of nine inches. That means if you cut the ball in half and measured straight across the circle, it would be nine inches from one end to the other. A beach ball is often about 12 or 16 inches in diameter. So a 36 inch diameter shell would be the size of a small table.

**John 13:21**

So if I want to perform a show, and I want to have a more precise display, and I want to use big shells, then I use electrical ignition. So we use a device called an electrical match. And it's two wires up to a wire that gets hot. When the current goes through it, the electricity goes through it. And it makes a spark and lights the fireworks. And then we go to level three, how do we get the really good time shows that are choreographed to music? And the answer is a computer program. But basically you have someone who scripts the program. That person builds in a computer program, the soundtrack and the cues for the fireworks. If I shoot a three inch shell in the air, it pops three seconds later. So you do a technique. It's called drag and drop. So where the note of the music is that you want the shell to burst on, you drag the cue for the shell back along your timeline. Whatever three seconds, four seconds and plug it in there, drop it in there. So what the computer does, is it's making sure the shells fire so the effect is displayed where you want it with the music.

**Jane** 14:34

So for example, if you were playing the US National Anthem, and you want some red fireworks to explode right on the line, and the rockets red glare, the bombs bursting in air, you'd need to shoot those fireworks into the air a few seconds before that point in the music. So they go off at exactly the right time. That's hard to do quite right if you're doing it by hand. A computer program helps get the timing perfect.

**Dash** 15:04

Hi, my name is Dash. And I'm four years old. And I live in Omaha, Nebraska. And my question is, why are fireworks bright?

**Jane** 15:21

Dash wants to know why fireworks are bright? Why are fireworks bright?

**John** 15:27

There are three reasons why fireworks are bright. One, you're painting in the sky, you're painting with light. So your firework has to be bright enough to create the color and effect you want to paint in the sky. Second answer, fireworks are explosives, you can't be right up in front of it like a painting in an art gallery, you have to be some distance away. So the fireworks have to be bright enough for the audience who's hundreds of feet away to appreciate it. And third, the types of things we burn in fireworks burn very brightly. And they're chosen for that property. So we can meet the first two requirements.

**Jane** 16:09

David Chavez says when the metals and the gunpowder start to burn, they get really, really hot.

**David** 16:16

And that hot temperature or very high temperature, it excites the the colouring agents that we have in fireworks. So those are the metals, so like barium or sodium or atoms like that. So it means you need a really, really hot fire to be able to excite these atoms to make them give off their color. But when they are that hot, it makes the colors come out like really, really bright. And so that's why the fireworks that you see like in Fourth of July fireworks, that's why they they have that sort of very luminous nature to them is because the the chemistry that's happening is creating really, really hot temperatures. And those hot temperatures are making the metals just really excited. And so excited that they're just giving off all of these colored lights out of them.

**Samuel** 17:13

Hello, my name is Samuel. I'm seven years old. I'm from London, England. And my question is why the fireworks make a bang sound?

**Sophie** 17:24

Hi, my name is Sophie. I'm four years old. I live in Omaha, Nebraska. And my question is, why are fireworks so loud?

**Jane 17:36**

The noise is just part of what it takes to get the firework to explode. David says you need all that energy to explode the shell ignite the chemicals and send those stars flying out.

**David 17:48**

It takes a lot of energy to burst that cardboard tube, because it's just a cardboard sphere. And so to break that it, it's going to take a lot of force, and sort of is sort of like hitting a nail with a hammer, you know, like when you hit it, you're gonna have to put some amount of force into the into the nail, but there's always going to be that noise associated with it. And so it's the, it's the same type of thing, you need force to break that stuff. And then the force itself creates the bang that you hear. So you're always going to have that, that effect. And you also need that effect in order to throw the stars out into the sky. Because without it, they would just stay in the little sphere and you would see just a bunch, a little bright ball of a burning color instead of like the little points of light that that go out.

**Jane 18:45**

Sometimes you hear in fireworks, not just the loud bang, but then there are some that I think they sound kind of like they're fizzing. So there's the loud bang. And then there's, you know, some sounds that they make, are those designed to make specific kinds of sounds or is that just because of the explosion in the chemicals too.

**David 19:02**

So those ones, there's there's different sound effects that that you can get. Some of what you hear, I think that you're describing is called like, like crackle or something like that. And so there's specific chemical compositions that are put together, that instead of burning smoothly, just like a candle would burn these things burn like those, those like trick candles, where they like kind of snap and they turn off, turn on turn off, turn off. And so what you're hearing is like the reignition and then the turning off. So it's like crackling just like on and off and on and off. So it's this combustion that sort of like repeating at a certain interval. And they're designed specifically to have that kind of an effect.

**Jane 19:52**

And similarly the ones that go whew whew, those are also designed to sound like that.

**David 19:57**

Yeah, they have sort of special features that allow them to when the gases are being generated to make particular sounds. Yeah.

**Jane 20:05**

Some of us like the noise that we've just been talking about in fireworks and some of us really don't. John Steinberg has advice for those of us who absolutely do not like fireworks.

**John 20:17**

Some people find it very upsetting. I have a couple of thoughts on that. One is fireworks are going to be a part of the Fourth of July. Some communities however, opt for laser displays, or no noise displays.

And if that's the sense of the community, that's one option. And then the people who like fireworks generally in the United States on the Fourth of July don't have to travel too far to find a community that likes fireworks. That's one option. Another option is if you're in a community that does fireworks, and you really don't like them. You may want to schedule a weekend or a holiday day way out in the country at a lake or something or find some place where people don't do fireworks. In 2020 with the COVID pandemic, for the first time in almost 30 years, I was home on July Fourth. And yes, my neighborhood was really jumping. My dog Kojak does not like fireworks and we spent about a half hour to an hour watching TV turned up pretty loud sitting on the couch in the living room, and he's cuddled up next to me, not liking it, but reassuring each other. So if you have to be around and you don't like it, kind of try to do the best you can to find something distracting, some loud music. If you really can't avoid it, be with people who can support you and share the moment with each other.

**Jane** 21:49

In just a minute we'll learn about how fireworks get a little more green. Literally.

**Jane** 21:54

This is But Why: a Podcast for Curious Kids. I'm Jane Lindholm. Today, we're learning all about fireworks. And now we're going to hear a little bit more about some of the really cool research one of our guests, David Chavez, has been doing. He's an explosives expert at the Los Alamos National Laboratory. Remember, aerial fireworks are a combustion in the sky. Combustion is the process of burning. And when things burn, they often create smoke. Sometimes fireworks have a lot of smoke. And that's not great for the environment or for people, especially in areas where fireworks are set off frequently, sometimes even every night. So David and other scientists at his lab have been trying to figure out how to make fireworks that create less smoke. But not only that, they're also trying to make fireworks with chemicals that are less toxic, less bad for the environment and for people. Because when you use fireworks, you're leaving materials behind.

**David** 22:55

What goes up must come down. So anything that's in the fireworks that can be turned into gases will come back down onto the soil. So one thing that could help with that is to reduce the amount of those metals which provide the colors as much as possible, or find alternative ways to make the colors. And then there's the smoke. And so when you have large fireworks displays and you're in a, in a urban environment, the The wind will blow that smoke into the surrounding communities. And you know, people don't really like that the smells can be, you know, problematic for people. And both of those things also apply to indoor pyrotechnics. One additional, one additional thing is that the fireworks themselves the big fireworks displays, they're typically in like cardboard casings. And so when those are used, the cardboard kind of debris always comes back down. And you know, it creates sort of like, it's like littering almost.

**Jane** 23:57

So the researchers at Los Alamos work to fix all three of those problems. And one of the most important ones they worked on was how to change the metal used in green fireworks.

**David** 24:08

The metal that is the most problematic is barium. So if you can, and barium makes green. So if you can come up with some alternative to make green, that still gives you the bright colors, then that would be really useful. So what we did was we came up with a different fuel. And typically the fuels that were being used were like carbon-based fuels like charcoal, or like sawdust or things like that. And when those combust, they can generate a lot of soot, a lot of smoke. The fuel that we came up with has a lot more nitrogen atoms and the molecules and so when they combust, they just make nitrogen gas and so there's much, much, much less of this soot that's generated.

**Jane 24:57**

So it is like smoky ash, which isn't great to breathe, but also makes it hard to see through.

**David 25:03**

So anytime you generate color you have essentially like an obscuring effect of the color. So it's kind of like looking through a fog. So when those metals get excited and generate their light, when the light has to travel through that smog, or that, that fog, you just can't see them as clearly and as brightly. And so you need to use more of the metal. But with these much cleaner burning fuels, there's almost none of that obscuring sort of feature. And so you can use like an almost an order of magnitude less coloring agent to get the same like brightness of the colors. And that effect allows us to use a different material called boron as the green coloring agent and, and gives us the potential to eliminate barium from fireworks, so, so you wouldn't have any of that barium, like getting into the soil and things like that.

**Jane 26:03**

That makes total sense I hadn't even thought about but of course, it makes sense that if you've got a lot of smoke generated by an explosion, you can't see the beautiful firework that you're trying to look at. So really, in any fireworks, you're probably trying to reduce that amount of smoke that happens right where the explosion is, right, because you want people to see the display, not trying to see through a kind of a hazy sky.

**David 26:28**

Correct. And so if you if you shoot, you know, shell after shell after shell, there's going to be a lot of smoke in the air. And so unless there's a wind sort of like dissipating it, the firework display is going to get progressively less bright because of the the obscuring nature of the smoke. That's that's up there. But if you have much less of that, then you can have the the brightness kind of shine through.

**Jane 26:55**

And David says now that they've created fireworks with less smoke, fireworks makers can make designer colors that weren't able to be seen before. Because the smoke made it too hard to see a difference in the color,

**David 27:07**

Like aquamarines, or like things that are bordering on like pastel colors, is sort of amazing how much of an impact just changing the fuel can have.

**Jane 27:20**

David and his team have done all kinds of work on fireworks. And a lot of the technology they created is used all over the world, which must be pretty cool to look up at a fireworks display and know you are partially responsible for what people are seeing. David says he does still watch fireworks and he watches them differently now than when he was younger.

**David 27:40**

I'm not familiar with a lot of the actual device construction. But I'm familiar with the the colors that I see. And so I can see a display and I'll say okay, I know they made that with these metals, or they did this with this other thing. Yeah, so it really is the case you know that if I look out at one of these fireworks displays, it's like oh, yeah, that's that's our stuff, right?

**Jane 28:07**

That must be a cool feeling.

**David 28:09**

Yeah, it is. It's pretty neat to see the progression of just the basic idea to then the application and people enjoy being able to enjoy, you know, something at a at an entertainment event.

**Jane 28:23**

I think when you're in a crowd, you should just yell at everybody. I help...

**David 28:26**

That's my stuff! They'll just think I'm crazy.

**Jane 28:35**

One other cool thing before we go, if you're interested in pyrotechnics, or chemistry, David Chavez says there's a lot more that still to be done on fireworks research. And one area of focus is in making sparklers better. Those are the long metal rods that sparkle and pop as you hold them in your hand.

**David 28:54**

The sparkler typically contains something like iron, or titanium, or maybe even aluminum mixed in with fuel and an oxidizer. So when you burn these, the metal start on fire, and so they essentially are burning in the air. And so there are these little tiny particles of metal. And each of them can sort of give like a different color too so when you burn an iron sparkler, you'll see more of like the yellowish kind of metal sparks that come out. When you burn a titanium sparkler. We're going to be more like white sparks. And one of the big challenges in fireworks right now with respect to like, generating sparks is can we make sparks that are like other colors like can we make red sparks or like green sparks or things like that. So that sort of a an area of research that's kind of ongoing that that is pretty interesting, and I think could be a place where more entertainment value could be found.

**Jane 29:59**

So not only could you be the scientist who someday figures out how to make a really red sparkler, but you can already impress your friends and family by telling them that's titanium when you burn a sparkler with white sparks or, oh, that's iron if your sparkler is yellowish.

**Jane 30:18**

That's almost it for today, but you didn't think we'd end without having a safety talk, did you? Safety is really important when it comes to fireworks. If you're at a fireworks show, it should always be put on by professionals and you should be a safe distance away. Remember John Steinberg, who we talked to earlier in the episode, he says fireworks operators have to follow lots of rules to keep themselves and the audience safe. But even so he wears safety glasses when he goes to watch a display and you can wear earplugs to keep the noise down too. As for the fireworks you can buy to set off at home, it's best to leave those to the adults. You should never use fire of any kind without an adult. John Steinberg says if you're curious about fireworks, there are lots of clubs and organizations that help young people safely learn about making and setting them off. And even with handheld sparklers. Remember, you're burning metal so they get really hot. If you're going to use sparklers, watch a safety video first. We have one in our show notes. And be sure you're wearing proper clothes like close toed shoes, pants and long sleeves if you're using things that spark. Okay, now that really is it for today. Thanks to Dr. John Steinberg and to David Chavez at the Los Alamos National Research Laboratory for helping us understand the physics and chemistry of fireworks.

**Jane 31:46**

What are you curious about? History, ethics, fashion, food? If you have a question about anything, have an adult recorded, it's easy to do using a voice recording app on a tablet or phone. Then you can email the file to [questions-at-ButWhyKids.org](mailto:questions-at-ButWhyKids.org) we can't put all of your questions in our episodes, but we always love hearing what's on your mind. But Why is produced by Melody Bodette me Jane Lindholm at Vermont Public Radio and distributed by PRX. Our theme music is by Luke Reynolds. We'll be back in two weeks with an all new episode. Until then, stay curious.