Radiation Basics Made Simple

Segment 2: Radioactive Decay

As we discussed in the previous segment, radioactive decay is a process in which a radioactive atom spontaneously gives off energy in the form of radio particles to reach a more stable state. Now, this process that we call radioactive decay can also be called disintegration, transition, transformation, they all essentially mean the same thing. But what's important to remember and distinguish between radioactive material that contains radioactive atoms and the radiation that it emits.

There are three types of radiation given off by radioactive atoms: alpha particles, beta particles, or gamma rays. Radioactive atoms may give off one or more of these types of radiation when they go through radioactive decay to reach a more stable state. In other words, a radioactive atom may give off an alpha particle and a gamma ray, or they may give off a beta particle and a gamma ray, or just an alpha particle. It just depends.

Each type of radiation- alpha, beta, or gamma- has different properties that would affect how we can detect it, and how it can potentially affect us. Alpha particles are sub-atomic particles, and they're actually pretty bulky. They don't travel very far in space because they bump into other atoms. The range of alpha particles in the air is up to 1 inch, and we can shield them very easily; they can be blocked by a piece of paper.

That means that alpha particles don't really represent an external hazard to us, as long as alpha particles are outside of our body they can't penetrate through clothing, and they can't penetrate through the external layer of skin. So, they don't harm us as long as they're outside. But they're a serious internal hazard if we internalize them, and they come inside our body, then alpha particles can damage your cells; so it's an internal hazard, not an external hazard.

Beta particles: they're also particles, not rays; they're very similar to electrons. And these have a longer range; they can go up to several feet in the air, and it will take maybe an inch of plastic or so to block beta particles. Many of them can penetrate a layer of clothing. If they're on skin they can cause skin burn. So, beta particles represent an external hazard on the skin, because they can penetrate the outer layer of the skin, but also internal hazard.

Gamma rays have a long range. They can go many yards in air, and it takes an inch or more of lead, several inches of lead, to block them completely. And they're also of course an external hazard because they can penetrate through material; they can penetrate through clothing; they will penetrate through plastic. And we'll talk later about how first responders need to be aware, because their protective clothing won't protect them against penetrating gamma rays. It takes lead to block those.

But there also can be an internal hazard. They're an external hazard, obviously. But if ingested, inhaled, radioactive material that emits gamma rays that could be exposing us to radiation from inside.

Now, detecting and differentiating alpha particles, beta particles, and gamma rays, is actually fairly easy if you have the right instrumentation. I'm going to demonstrate that to you. This particular instrument is a Geiger-Mueller instrument, GM probe; this is a pancake-style of instrument. This is a very versatile equipment which is commonly used, and there are many different manufacturers that make these. And it can detect all three types of radiation – alpha, beta, and gamma. It is designed for surface contamination for beta particles. But like I said, it can detect all three forms of radiation.

And there are more specialized equipment too. I have one detector here that's specialized for detection of alpha particles. I want to demonstrate alpha particles, I'll use this particular instrument. So, let's begin. I have some check sources too. These sources have a very small quantity of radioactive materials that are fixed to the surface, so they don't come off. And I have here to demonstrate to you.

I'm going to start with the alpha particles. And actually, for a source of alpha particles what I have here is Americium 241. Americium 241 is a man-made radionuclide, so it doesn't happen naturally in nature. We don't find it naturally; it's a man-made radionuclide. It's commonly used in household smoke detectors. The particular piece that I have here actually came from a household smoke detector. Now, you'll wonder why do you have Americium 241 in a smoke detector. The reason it's there is that Americium 241 gives off alpha particles, and these alpha particles ionize air molecules inside the smoke detector, and those create a small electrical current.

So, when smoke enters into the smoke detector, smoke particles attach to these charged particles and disrupt the current; that'll set off the alarm. It's a very sensitive instrument. So, we have this Americium 241 here, and I've said we can detect them with both of these, but I'm going to use this particular instrument. And remember, alpha particles have a short range in air, and they can be stopped easily with a piece of paper. So, we're going to see if that's true.

So, there's alpha particles being emitted here. See, I can't see it here, but if I put it right on top if I move up the detector a little bit, because I'm about an inch off, then I can no longer see it. Because alpha particles have this limited range in air, they can be stopped in air like that. And now let's see if I put it right on top like that, you hear the counts, and when I put the paper on top of it, and right on top, nothing. So, I slipped the paper out just like that.

So, this piece of paper can stop alpha particles, and so they're easily shielded. And what that means is that alpha particles are not an external hazard. What I mean by that, means that first of all if you have a lot of alpha particles here, they can't reach us, so they have a very short range in air. If we have it in our clothes, they can't penetrate our clothing. And if they are on skin, they can't penetrate the dead layer of skin. But they are, of course, a hazard if we internalize them by getting them inside of our bodies.

So now I'm going to demonstrate a beta particle, and we're going to use Strontium 90 for the beta particle source. So, you can see it has a higher range than alpha particles, because I can still see it. And this piece of paper shouldn't do much. Strontium 90 has a pretty energetic beta particle, so it will go right through paper. But now I can block it with a piece of plastic. Here– plastic shield. Here, you can see it here.

So, as I put the plastic right between the source and the detector, the counts are gone. So, this is an effective shield for beta particles. So, beta particles do present an external hazard, because even though clothing can offer some protection, some of the energetic beta particles can go through clothing. But certainly, if they're on skin they can go through the outer layer of skin and cause skin burns, and they're also an internal hazard.

Now let's move on to gamma rays, and the source we have here is Cesium 137, of course the cesium. Now to block cesium, it takes lead to block it. I have two sheets of lead; it comes maybe to less than half an inch. And let's see if I can hold this and do it; I'll put it on top like that. See, I'll put this – so it's not all gone; it cuts it. But that's the effect of lead. So, it takes lead to shield gamma rays. Gamma rays are obviously an external hazard, because for example first responders, if they show up on a scene and their protective clothing cannot stop penetrating gamma rays; they will go right through that. So, it's an external hazard that needs special attention.

Another feature of each radionuclide is its half-life, that is, the length of time it takes for half of the radioactive atoms in a population of radionuclides to decay. And I'll show it to you in an example.

Imagine we have 100 radioactive atoms sitting here, and after one half-life half of them would decay to a more stable state, and we will have 50 left. After another half-life we would have 25. And after another half-life, we would have 12, and then 6, and then 3, and then 1, and eventually all of the radioactive atoms that we started with have decayed to a more stable state. So, half-life.

And each radionuclide has its own specific half-life. And a good rule of thumb for every radionuclide is that after seven half-lives, less than 1 percent the original number are still around. And this half-life can range from microseconds to billions of years. So, the half-life varies depending on radionuclide; some have very short half-lives, microseconds, and some have very long half-lives measured in billions of years.

To give you a couple examples, most radionuclides used in nuclear medicine have short half-lives, because we don't want them in the patient for too long. Technetium 99 is the most common radionuclide used in imaging studies. That has a half-life of six hours. So, one feature of a radionuclide with a short half-life is that later when we talk about environmental contamination, if you have an event, an incident, that involved contaminating the area or the room, but the contaminant has a short half-life, that means it will decay really quickly and go away. So, something that has a six-hour half-life, after just 24 hours more than 90 percent of it is gone.

On the other hand, uranium has an extremely long half-life. The half-life of Uranium 238 is 4.5 billion years. Remember, that's the primordial radionuclide that's been part of the earth's crust. It's in our soil and rock. So, we still have plenty of it around, and in fact, if we take a soil sample from the backyard, you're going to find Uranium 238 in there.

Now before we leave the subject of radioactive decay, one last point to make is that some radionuclides need to go through a series of transformations before they reach a stable state. There's more than one radioactive decay process through a series of steps. And again, the uranium we were just talking about is a good example of that, because it goes through a series of transformations before it'll reach a stable state.

Starts with uranium, goes through thorium, radium, then radon, bismuth, and then ultimately stable lead. So, an atom that starts as uranium finally ends up happy as a lead atom, but it takes it quite a long time sometimes.

As a result of this natural process, all of these radioactive atoms are now part of our natural environment.