MARKUS KLUTE: Welcome back to 8.701. So in this lecture, we talk about nuclear fission. Already seen the process when we discussed empirical mass formula.

Nuclear fission occurs in very heavy nuclei, as you can see in this plot here, fission processes, and this part of the spectrum. But what happens, and what can happen spontaneously, is that the parent nuclei just simply breaks up into daughter nuclei and maybe some additional neutrons. One example is the decay of uranium 238.

One can also induce fission. Here, is a plot of the nuclear potential with the Coulomb [? law ?] here. And for example, you have this nuclei which sits here-- and this could be uranium 238-- and you are able to bring it above this activation and energy. Again, this can, in some nuclei, occur spontaneously, in others, it's being induced. And then you just break up the two, break up the nuclei into two daughter particles.

So if you, for example, start with a neutron and you just bring it close-- let's say you bring a neutron close to uranium 235. This forms uranium 236. And the fact that the neutron is being absorbed excites, then, this zero-kinetic energy neutron excite the daughter compound nucleus. There's an excitation [INAUDIBLE] in this case, of 6.5 MeV. And because of that, it then quickly undergoes fission.

So we basically add its thermal, or zero-kinetic energy neutron, and when it's being absorbed it immediately causes the fission process. The fission fragments then carry away some energy-- in this example, here, it's about 180 MeV-- and additional prompt neutrons. And so those additional prompt neutrons, depending on the specific decay process, the number can be varying between zero and six, and for uranium 235, the average number is 2.5.

And then the fragments, they might undergo additional decay process, maybe better decays, alpha decays. And when they do that, they can also release additional neutrons. So interesting, now, is to see whether or not there can be a self-sustained reaction, a chain reaction. And whether or not this occurs depends on the number of neutrons being emitted.

So if the number of neutrons produced in the n plus first stage of the fission process is greater than the number of neutrons produced in the nth stage of the process, the process is either critical or super critical, which means that it is able to, because it produces more neutrons and it needs to continue to have a fission process, it will add or create a chain reaction. If the number is less than 1, the process will die out.

And this is exactly what's used in nuclear fission reactors. There's several types of reactors available. The example I want to discuss here very briefly is the one of a thermal reactor which uses uranium as fuel and low-energy neutrons to establish the chain reaction, as we just discussed.

And so this is a sketch here. And the sketch has three different elements. The first one is a fuel element. The fuel element can be naturally-occurring uranium.

And then, we have a moderator material. And the purpose of the moderator material is to slow the neutrons down. So if you really start from naturally-occurring uranium, you might have to find some sort of material which allows you to efficiently slow down the neutrons when they're being emitted in the fusion process. And this could be, so-called, heavy water, where the hydrogen in water is replaced in part that leaves this deuterium. But there's other examples for this as well.

And then, you have those very important retractable rods. They are materials which have a large cross-section to capture neutrons. And so what you can do with them by mechanically adding them or removing them from this environment, is you can remove additional neutrons.

So what you're trying to do is control this number k here, control whether or not there's enough neutrons available in order to sustain the chain reaction. And then, the excess energy is converted in heat. You can, for example, heat up water and then just have a turbine run in order to produce energy.