

PhET Nuclear Fission Inquiry Lab

After using this simulation, you will be able to:

- Describe how a neutron can give energy to a nucleus and cause it to fission.
- Explain the byproducts of a fission event.
- Explain how a chain reaction works, and describe the requirements for a sustained chain reaction large enough to make a bomb.
- Explain how a nuclear reactor works and how control rods can be used to slow down the reaction.

Use the Nuclear Fission Inquiry Lab Nuclear Fission PhET simulation at <http://phet.colorado.edu/en/simulation/nuclear-fission> to answer the questions on this page

1. Use the tab called "Fission – One Nucleus" to answer these questions:
 - a. Try to figure out how you can make U-235 unstable
 - b. How do you know it's unstable?
 - c. Describe what you would do to make U-235 unstable, both in terms of what you see and do in the simulation and what this represents, physically.
 - d. In your own words, what does "unstable" mean when used to describe Uranium?

2. Imagine that you have many U-235 atoms and you fire a neutron at one of them. What do you think will happen? Explain your prediction using words and drawings.

3. Explore the features of the "Chain Reaction" tab. If you wanted to explain nuclear chain reactions to someone, what would you tell them? Briefly, explain your ideas using appropriate vocabulary and drawings. Make certain that your answer explains why the reaction occurs AND what affects the speed of the reaction.

4. Why is U-235 a good isotope of Uranium for creating chain reactions?

5. Now, you want to make an atom bomb. Use an Internet search to determine which materials are used for nuclear bombs, and use these materials to try to make your bomb. (Remember, a bomb must be transportable – what do you need to do so that it is transportable?) What can you do to make the bomb explode?

6. While using the simulation, what observations have you made that makes nuclear reactions good for bombs?

7. What are at least three things that you need in order to make an effective bomb, and why?

8. Explore the features of the “Nuclear Reactor” tab. What is the purpose of the control rods within a nuclear reactor?

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You need to use the neutron gun to fire a neutron at the atom. This changes U-235 to U-236 through the addition of a neutron. U-236 is unstable and quickly fissions into two daughter nuclei. "Unstable" means that the nucleus has too many neutrons to hold itself together. You can tell that the nucleus is unstable because it breaks into two daughter nuclei, and because the energy graph shows that this is in an energetically unstable state (i.e., the split atom is lower energy than the unsplit U-236). There is no magic ratio of neutrons to protons that is always stable – it depends on the particular atom.

2. Imagine that you have many U-235 atoms and you fire a neutron at one of them. What do you think will happen? Explain your prediction using words and drawings.

Student answers will vary. As they will see in the next step, the daughter nuclei from the induced fission of the first U-235 atom will induce fission in the rest of the atoms.

3. Explore the features of the “Chain Reaction” tab. If you wanted to explain nuclear chain reactions to someone, what would you tell them? Briefly, explain your ideas using appropriate vocabulary and drawings. Make certain that your answer explains why the reaction occurs AND what affects the speed of the reaction.

A nuclear chain reaction is when the products of one nuclear fission (i.e., the daughter nuclei from a split atom) prompt the fission of additional fissionable atoms, which prompt the fission of more atoms. The chain reaction only occurs if this process self-perpetuates; that is, enough fissionable atoms are present so that the products of each fission are likely to hit another fissionable atom.

4. Why is U-235 a good isotope of Uranium for creating chain reactions?

U-235 is ideal for creating a chain reaction because it splits into two daughter nuclei. Only one daughter nuclei is necessary to induce fission in another U-235. So, since the number of fission products is more than the number required to induce fission, the chain reaction keeps going.

5. Now, you want to make an atom bomb. Use an Internet search to determine which materials are used for nuclear bombs, and use these materials to try to make your bomb. (Remember, a bomb must be transportable – what do you need to do so that it is transportable?) What can you do to make the bomb explode?

The bomb must have a containment vessel and include both U-238 and U-235, since in the real world most Uranium is U-238. U-238 is not fissionable, and the chain reaction does not continue with a high ratio of U-238. Thus, weapons-grade Uranium (which naturally contains more U-238) is enriched with U-235.

6. While using the simulation, what observations have you made that makes nuclear reactions good for bombs?

Each nuclear fission releases energy (as can be seen by the energy graph on the Fission: One Nucleus tab). The fission of a small number of atoms can trigger the fission of a large number of atoms, and thus the release of large amounts of energy.

7. What are at least three things that you need in order to make an effective bomb, and why?

- a. *It needs to include some fissionable nuclei (i.e., U-235). Otherwise, there is no chain reaction.*
- b. *Each induced fission must create more daughter nuclei than are needed to create a new fission event (see #4 above).*
- c. *There must be a large enough ratio of fissionable nuclei (i.e., U-235). Otherwise, the chain reaction does not reach all the nuclei. This ratio is reached when each fission*

creates – on average – more than one daughter nuclei, so that a chain reaction will occur. That means we must have more U-235 than U-238.

- d. *The U-235 must be densely spaced enough so that the daughter nuclei are likely to hit another U-235 before hitting the container wall or escaping to the outside.*

8. Explore the features of the “Nuclear Reactor” tab. What is the purpose of the control rods within a nuclear reactor?

They control the rate of fission of the uranium in the reactor by absorbing neutrons and daughter nuclei. When partially removed, they allow a chain reaction to occur. Thus, the presence of control rods allow the reaction to be slowed or stopped, preventing the nuclear reactor from becoming a nuclear bomb.

