Energy Education Resources

Critical Mass Activity

Adapted from the American Nuclear Society

Prep Time: 30 minutes to gather materials

Activity Time: 30 minutes

Materials:

- Student Data Collection Sheets
- 1 Stopwatch per group of students
- Balloons, ping pong other lightweight balls (2 per student)

North Carolina Education Standard: PSc.2.3

- **PSc.2.3.1** Compare nuclear reactions including alpha decay, beta decay and gamma decay; nuclear fusion and nuclear fission.
- **PSc.2.3.2** Exemplify the radioactive decay of unstable nuclei using the concept of half-life.

South Carolina Education Standard: H.P.3

- **H.P.3G.2** Develop and use models to communicate the similarities and differences between fusion and fission. Give examples of fusion and fission reactions and include the concept of conservation of mass-energy.

Background

Nuclear fission is the splitting of a nucleus into two fragments, each with a smaller mass than the original. A typical example of nuclear fission is the splitting of a uranium-235 nucleus. This is a reaction that is used in nuclear reactors to generate heat by which steam is produced and used to turn turbine generators that make electricity.

The fission of uranium-235 begins when the uranium-235 nucleus captures a slow moving neutron and forms an unstable “compound nucleus.” The compound nucleus quickly disintegrates into two smaller nuclei and a tremendous amount of energy (~200 million electron volts per fission).

Because the uranium-235 fission reaction produces two or three neutrons, it is possible for those neutrons to initiate a series of subsequent fission reactions. Each neutron released can initiate another fission event, resulting in the emission of more neutrons, followed by more fission events and so on. This is a chain reaction – one event triggers several others, which in turn trigger more events, and so on.

In a nuclear power plant the chain reaction is controlled by restricting the number of neutrons available to collide with the uranium. This is accomplished by absorbing some of the released neutrons with various materials.

There are two parameters needed to create a critical mass, the number of atoms and the spacing of the atoms. In this demonstration, each student represents a uranium atom inside a nuclear reactor. Each uranium atom releases two neutrons when it fissions.

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Procedure

1. Arrange the students in a square array approximately three feet apart and give each student two balloons or lightweight balls.

2. Designate a time keeper to time and record how long each reaction lasts which is when the last balloon is thrown in the air.

3. Take a balloon for yourself. To begin the activity, throw your balloon up into the air. Any student that is hit with this balloon throws their two balloons straight up into the air. Any student hit by these balloons then throws their balloon into the air. The reaction continues until there are no more balloons in the air. The first time, the reaction will probably die out quickly, this is called subcritical.

4. Repeat the process, but place the students only 1 foot apart this time and carry out the activity. This time, the reaction should be self-sustaining. This is called critical and a critical reactor is running at a steady state.

5. Repeat the process a final time, but place the students in a tight array without any space between them. This time, there should be lots of balloons in the air at one time. This represents a supercritical mass, or when a reactor is increasing its power level.

Discussion

1. What happened during each trial and why?

2. Discuss the differences between subcritical, critical and supercritical masses.

3. How did the different arrangements of students affect the reactor reaching subcritical, critical and supercritical masses?

4. How do you think nuclear power plant operators use this concept to power up or power down?