Nuclear Fission with Ping Pong Balls

Models to Understand Scientific Phenomena

Student Worksheet

Students solve problems by:

- using modelling (including mathematical examples) to explain phenomena, make predictions and solve problems using evidence from primary and secondary sources
- using scientific evidence and critical thinking skills to solve problems

Students will:

- model a nuclear chain reaction
- apply this model to explain how a nuclear chain reaction occurs
- explain the advantages and limitations of the model
- visualise what is meant by nuclear fission
- use critical thinking skills to improve the model

Note: This activity works best with large groups of students, however can also be done online at home.

Contents

Background

The splitting of a massive nucleus into two fragments, each with a smaller mass than the original, is known as nuclear fission. Inside a nuclear reactor nuclear fission occurs with the splitting of Uranium-235 nuclei. Each Uranium-235 fission produces 2 or 3 neutrons. This process is accompanied by the release of a large amount of energy.

The neutrons released during the fission process need to be slowed down by a moderator such as heavy water before they can fission another Uranium-235 nucleus. Each neutron released can initiate another fission event, releasing more neutrons, followed by more fission events. This process is called a chain reaction.

In a nuclear reactor, the chain reaction is controlled by restricting the number of neutrons available to collide with the Uranium-235 nuclei. This is done using materials that absorb some of the neutrons from the fission reaction. In an uncontrolled chain reaction there is nothing to control the number of neutrons being released, so the rate of the chain reaction increases dramatically.

ANSTO operates the Open Pool Australian Light water (OPAL) reactor, the only nuclear reactor in Australia. OPAL uses the fission of Uranium-235 nuclei to produce neutrons of different energies, and operates for more than 300 days every year. In the OPAL reactor the moderator used to slow the neutrons is heavy water and hafnium control plates are used to control the rate of the fission chain reaction.

For this activity students will model the fission chain reaction. A model is a representation that describes, simplifies, clarifies or provides an explanation of the workings, structure or relationships within an object, system or idea. In science models are extremely useful in understanding scientific phenomena. Students will be able to understand the process of nuclear fission and apply their understanding to how the OPAL reactor works.

Aim:

To investigate a model of a nuclear fission chain reaction in a nuclear reactor.

Materials:

- At least 50 Ping Pong Balls (two per student plus a few extra)
- At least 20 students (this demonstration works best with a large number of students: the larger the number of student participants, the better the results)
- At least one teacher

Risk Assessment:

Risks Identified	Risk Management
Physical injury from ping pong balls	To prevent eye injuries students must throw their ping pong balls straight up into the air when struck by a ping pong ball, and not throw them directly at other students.
Physical injury from bumps from other students	While students should stand close together, ensure there is sufficient space to prevent possible injuries (elbowing in face) when students throw ping pong balls up in the air.

Instructions:

1. Students stand in a tight bunch, with each student holding two ping pong balls. Each student represents a Uranium-235 atom and the ping pong balls represent neutrons.
   Or
   Students are to perform this activity seated in a tight bunch. This will enable students to see the dramatic increase in the number of ping pong balls in the air after the initial throw.

2. The teacher/s, holding a ping pong ball each, stand outside the bunch of students. The teacher/s throw their ping pong balls into the bunch of students. Ping pong balls from the teacher/s represent the initial neutrons from a neutron source.

3. When a student is hit by a ping pong ball, they need to throw their two ping pong balls straight up into the air, so that they fall and hit nearby students. When hit, these students will then throw their ping pong balls up to hit other students, and so on.

Note: Allow the activity to proceed until most students have released their ping pong balls or until the chain reaction slows down.

If you are unable to perform the ping pong ball activity with a class of students, select one of the online **Mouse Trap Reactor models** below to complete the discussion questions.

- http://nuclearconnect.org/in-the-classroom/for-teachers/mouse-trap-reactor
- https://www.youtube.com/watch?v=UlcjtWp4vAA
- https://www.youtube.com/watch?v=yNWAbMtftq4
- https://www.youtube.com/watch?v=BzafqbVIldU

Discussion:

Using the information provided in the suggested resources and others, complete the discussion questions below.

1) Did all students or mousetraps throw their ping pong balls? Why/why not?

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2) Is this a controlled or uncontrolled chain reaction of nuclear fission? Why?

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3) How is the chain reaction controlled in the OPAL reactor?

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4) Which aspects of this model accurately represent the fission process in a nuclear reactor?

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5) What are the advantages and limitations of this model of the nuclear fission process in a nuclear reactor?

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6) Using your knowledge of the fission process, and your assessment of this model, explain how you could modify this model to better show the process of a nuclear fission chain reaction in a nuclear reactor?

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7) Describe a model that you have previously used in science. Explain how this model helped your understanding of the concept.

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8) What are the advantages and limitations of using models in science?

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9) View the PhET Interactive online simulation of nuclear fission.
https://phet.colorado.edu/en/simulation/legacy/nuclear-fission
Choose the tab *Chain reaction*. Choose 50 uranium-235 and 10 uranium-238 atoms and repeat the simulation 3 times.
Compare this simulation of a chain reaction with the model you have used of a nuclear chain reaction. (Hint: what are the similarities and differences between these two models?)

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10) Describe some products that are created using the neutrons produced during fission in the OPAL reactor.

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11) Describe two shutdown systems that OPAL uses to stop the nuclear chain reaction.

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Suggested resources:

[1] ANSTO News. (2014). OPAL research reactor (video). https://www.youtube.com/watch?v=GooWJywwfgo

[2] ANSTO. (2016). Australia's OPAL research reactor (video). https://www.youtube.com/watch?v=EiAkeIzSIGg

[3] ANSTO. (2020). How safe is OPAL? (website). https://www.ansto.gov.au/about/how-we-work/how-safe-is-opal

[4] American Nuclear Society. (2020). Fission demonstration. (website). http://nuclearconnect.org/in-the-classroom/for-teachers/what-is-fission

[5] American Nuclear Society. (2020). Mouse trap reactor. (website). http://nuclearconnect.org/in-the-classroom/for-teachers/mouse-trap-reactor

[6] American Nuclear Society. (2020). Nuclear chain reaction using dominoes. (website). http://nuclearconnect.org/in-the-classroom/for-teachers/nuclear-chain-reaction-using-dominoes

[7] PhET Interactive Simulations. (2020). Nuclear fission. (online simulation). https://phet.colorado.edu/en/simulation/legacy/nuclear-fission