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| Simulation from a Nuclear Reaction |
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# Conceptual Model

## Overview

The nuclear reaction simulation is a 2D representation of a nuclear reaction that occurs when the lithium and deuterium atoms[[1]](#footnote-1) are excited by an external energy; they combine chemically and produce a Beryllium atom[[2]](#footnote-2) and enough energy to excite 2 more lithium and deuterium atoms. A chain reaction of excitation and fusion (creation of Beryllium atom) occurs. The corresponding Beryllium over time becomes helium atoms. This is referred to as the ½ life of the reaction. Figure 1[[3]](#footnote-3) is a pictorial representation of the reaction.

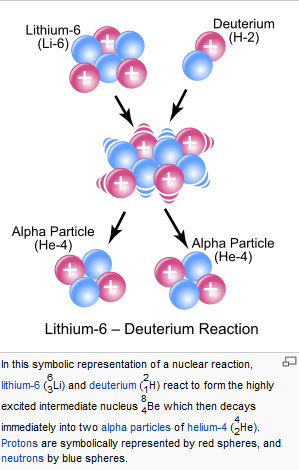


Figure 1: Nuclear Reaction

## Nuclear Reaction Model

There are two (2) phases within this simulation, they are the chain reaction of the excitation of the atoms and the decay of the excited resultant of the reaction. The decay commences at the coolest (the area that has been unexposed continuously the longest) portion of the reaction and proceeds to the hottest (latest) portion of the reaction. The decay pattern is based on the igniter locations used.



Figure 2: Li-6 or H-2 Neighbourhood



## Nuclear Reaction Simulation Rules

## Excitation

The excitation is represented as:

* The neighbourhood is restricted to the adjacent cells see Figure 2;
* Priority of the Li-6 cells to react with H-2 cells are bottom, top, right and left;
* The reaction commences with an excitation of 1 Li-6 and 1 H-2;
* Each reaction requires 1 Li-6 and 1 H-2;
* Each reaction produces 1 Be-8 in the Li-6 position (reference Figure 3);
* Each reaction produces 1 empty cell;
* Each reaction produces adjacent excitations;



Figure 3: Be-6 Following Excitation

## Decay

* The ½ life is 12.3 years[[4]](#footnote-4);
* At ½ life the single Be-8 becomes 2 H-2 (see Figure 4)



Figure 4: He-4 at Nuclear Reaction ½ Life



# Formal Specification

The formal specification for the simulation is as follows:

C : Li-6, H-2, Be-8, He-4

S : 6, 2, 8 and 4

ƞ = 2D (20x20)

N = nine (9) – all neighbouring cells and itself

T : global transition function – outcome of all the Ƭs in all the cells.

Ƭ : is a function of the cell’s current state, state of the neighbouring cells and the phase of which the cell is in within the global transition (excitation or decay).

Inertial delay is used to ensure scheduled outputs are trumped.

Border is unwrapped.

## 

Figure 5: Nuclear Reaction Simulation Triggers

Figure 5 shows the igniters in red. The igniters in this occurrence are Be-8, the Be-8 have sufficient energy to have the reaction between the Li-6 (brown) and the H-2 (neutral). When excited (Be-8 in excited state and the chain reaction state) as shown in red and yellow respectively (refer to Figure 6) the reaction between Li-6 and H-2 occurs. Eventually following the reactions the Be-8 decays to He-4. The He-4 is shown in the neutral tone.



Figure 6: Nuclear Reaction Simulation Triggers

# Results

The results show that for a quantity of 198 atoms (20x20) each of Li-6 and H-2, the simulation requires four (4) triggers for a full reaction to occur (no remaining Li-6 or H-2). For the purpose of the simulation the triggers used was Be-8 to initiate the chain reaction. This is demonstrated in the nuclearReaction.avi file.

The mushroomCloud and the nuclearReaction simulations are different. There is only one reaction stage in the mushroomCloud and when the mushroomCloud is scaled to a larger size, the quantity and location of the triggers remain the same. The time to reach decay increases with the size of the simulation. When the quantity of atoms was doubled the mapping of the triggers to the larger size was scalable.

The nuclearReaction simulation has a 3 state transition (Li-6 and H-2 transitioning to a Be-8 excitation, followed by a chain reaction of excitations, decaying to the He-4) and a multiple type combination required for state transition (Li-6 and H-2 combination). It is more complex than the mushroomCloud (2 state transition and a single combination). When the quantity of atoms was reduced to half (10x10), the total number of triggers required to ensure all atoms react was the same and the locations of the triggers were the same. When the quantity of atoms was increased proportionately the triggers were not scalable and had to be repositioned to ensure a full reaction.

# Discussion

In developing a nuclear reaction simulation, it became apparent that location of the reaction triggers is key to optimization of the reaction itself as well as the simulation is not scalable as a one to one mapping. To increase or decrease the mass of the reaction requires relocating of the reaction triggers as well as increasing or decreasing the quantity of triggers as required in order to maintain an optimal reaction. An optimal reaction occurs when all of the reactants are utilized in the simulation when the reactants are in equal quantities to support the reaction. These two (2) findings during the development of the simulation emphasized the requirement to model and simulate the system prior to implementing the system. Developing a nuclear system based on trial and error is expensive and will have negative repercussions.

1. These atoms are charged ions. [↑](#footnote-ref-1)
2. A highly charged atom. [↑](#footnote-ref-2)
3. The figure is taken from <http://en.wikipedia.org/wiki/Nuclear_reaction> . [↑](#footnote-ref-3)
4. Staff of Research and Education Association, Handbook of Mathematical, Scientific, and Engineering Formulas, Tables, Functions, Graphs, Transforms. For the purpose of the simulation the ½ life will be limited to a time-frame that is sufficient to indicate a pause prior to decay. [↑](#footnote-ref-4)