

The **Build a Nucleus** simulation allows students to explore how changing the number of protons and neutrons affects the nuclear species, the stability of a nucleus, and its possible decay mechanisms. Students can discover stability and decay trends in the isotopes.

Decay Screen

Build a nucleus from protons and neutrons, and discover the effect on atomic number and species. Determine how different decays change the nucleons in the nucleus.

OBSERVE the half-life change with the isotope.

OBSERVE the stability and isotope name change with the nucleus.

DRAG and **SEND** in protons and neutrons.

PREDICT the symbol of the isotope.

DECAY the isotope and **OBSERVE** these particle changes in the nucleus.

UNDO the decay to return to the previous isotope.

Chart Intro Screen

Change the nucleons in the nuclear shell model and observe the nuclides and the possibly decays in a partial version of the nuclide chart.

SEE INSIDE the nucleus and **OBSERVE** the nucleons involved in decays.

OBSERVE how nucleons in the energy levels move and vary between levels.

REVEAL the relationship between the chart and the periodic table; **DRAG** nucleons into the nucleus.

SEE the decay path of nuclides.

HIGHLIGHT isotopes with magic numbers.

Customization Options

Query parameters allow for customization of the simulation, and can be added by appending a '?' to the sim URL, and separating each query parameter with an '&'. The general URL pattern is:

```
...html?queryParameter1&queryParameter2&queryParameter3
```

For example in Build a Nucleus, if you would like to set the starting number of nucleons on the Decay screen to 40 protons (`decayScreenProtons=40`) and 40 neutrons (`decayScreenNeutrons=40`) use:

https://phet.colorado.edu/sims/html/build-a-nucleus/latest/build-a-nucleus_all.html?decayScreenProtons=40&decayScreenNeutrons=40

To run this in Spanish (`locale=es`), the URL would become:

https://phet.colorado.edu/sims/html/build-a-nucleus/latest/build-a-nucleus_all.html?locale=es&decayScreenProtons=40&decayScreenNeutrons=40

 Indicates this customization can be accessed from the Preferences menu within the simulation.

Query Parameter and Description	Example Links
<code>decayScreenNeutrons</code> - specifies the number of neutrons in the nucleus in the Decay screen. Values from 0 (default) to 146 allowed, but must result in existing nuclides. Use with <code>decayScreenProtons</code> as necessary.	<code>decayScreenNeutrons=6</code> <code>decayScreenNeutrons=28&decayScreenProtons=20</code>
<code>decayScreenProtons</code> - specifies the number of protons in the nucleus in the Decay screen. Values from 0 (default) to 94 allowed, but must result in existing nuclides. Use with <code>decayScreenNeutrons</code> as necessary.	<code>decayScreenProtons=1</code> <code>decayScreenProtons=20&decayScreenNeutrons=28</code>
<code>chartIntroScreenNeutrons</code> - specifies the number of neutrons in the nucleus in the Chart Intro screen. Values from 0 (default) to 12 allowed, but must result in existing nuclides. Use with <code>chartIntroScreenProtons</code> as necessary.	<code>chartIntroScreenNeutrons=4</code> <code>chartIntroScreenNeutrons=12&chartIntroScreenProtons=4</code>
<code>chartIntroScreenProtons</code> - specifies the number of protons in the nucleus in the Chart Intro screen. Values from 0 (default) to 10 allowed, but must result in existing nuclides. Use with <code>chartIntroScreenNeutrons</code> as necessary.	<code>chartIntroScreenProtons=1</code> <code>chartIntroScreenProtons=4&chartIntroScreenNeutrons=12</code>
<code>screens</code> - specifies which screens are included in the sim and their order. Each screen should be separated by a comma. For more information, visit the Help Center .	<code>screens=1</code> <code>screens=2,1</code>
<code>initialScreen</code> - opens the sim directly to the specified screen, bypassing the home screen.	<code>initialScreen=1</code> <code>initialScreen=2</code>

Query Parameter and Description	Example Links
⚙️ <code>locale</code> - specify the language of the simulation using ISO 639-1 codes. Available locales can be found on the simulation page on the Translations tab . Note: this only works if the simulation URL ends in “_all.html”.	<code>locale=es</code> (Spanish) <code>locale=fr</code> (French)
<code>allowLinks</code> - when <code>false</code> , disables links that take students to an external URL. Default is <code>true</code> .	<code>allowLinks=false</code>
<code>supportsPanAndZoom</code> - when <code>false</code> , disables panning and zooming using pinch-to-zoom or browser zoom controls. Default is <code>true</code> .	<code>supportsPanAndZoom=false</code>

Insights into Student Use

- There are various isotopes that do not form, thus the general pattern to quickly reach larger isotopes in the Decay screen, would be to use a combination of adding protons and neutrons at the same time (easiest with the double arrow button) and adding many consecutive neutrons.
- In the Chart Intro screen, students may not notice the significance or difference between valence and non-valence nucleons where only valence nucleons are interactive and therefore farther apart from each other on their energy levels.
- Students may not initially understand the significance of magic numbers which increase stability in isotopes, especially isotopes that have both neutrons and protons with magic numbers, known as a "doubly magic" nuclide.

Model Simplifications

- Technical details about the underlying model can be found [here](#).
- Only nuclides that exist on Earth can be built, this is done through the disabling of arrows, as well through briefly displaying “{{nuclide name}} does not form” when a nuclide that does not exist is built, then the nucleus rearranges itself back to the last formed nuclide.
- Five decay types are represented within the simulation: α decay, β^+ decay, β^- decay, proton emission, and neutron emission. Unstable nuclides decay into stable nuclides through one of these decay paths.
- Although decays can involve neutrinos, that aspect is beyond the scope of the simulation and thus not represented here.
- The size of the particles is not to scale, nor is their placement entirely accurate. This was done so that the particles could be easily seen and manipulated by the users.
- The electron cloud size is based on experimental data of the atomic radii of elements but its tweaked to make the electron cloud appear our desired size.

Suggestions for Use

- Explore the nuclides and all the various decays in the Decay screen. Determine which nuclides tend to be more stable and less stable using the half-life timescale. Determine how the nucleus is changed with each type of decay.

- Explore the partial nuclide chart in the Chart Intro screen through changing the nucleons in the nuclear shell model. "Zoom into" the partial nuclide chart and decay a nuclide to walk-through the chart. Determine which nucleons in the energy levels are changed.

Sample Challenge Prompts

- In the Decay screen, build an unstable isotope with an available decay. Using the decay icon symbols, determine the final symbol of the resulting isotope from this decay.
- Given an isotope with 12 or less protons and 12 or less neutrons, determine the nuclear shell model depiction of this nucleus. How many nucleons would there be on each energy level?
- In the Chart Intro screen, build an unstable isotope. Using its position on the chart, determine the decay equation of the isotope and predict this isotope's resulting position on the chart after it decays.
- Highlight the magic numbers on the chart. After you have built some isotopes, discuss with your partner what you think magic numbers are.

See all published activities for Build a Nucleus [here](#).

For more tips on using PhET sims with your students, see [Tips for Using PhET](#).