

# LEGO Chart of Nuclides

## Limits of stability

### Step 1 Isotope vital statistics

A nucleus is a combination of protons (which determine the element) and neutrons (which determine the isotope). The Chart of Nuclides places each combination in its own location, so instead of listing just elements like the periodic table, it lists all isotopes too.

The first step is to build the entire chart with your team. Each isotope is represented by a white tile attached to a large grey baseplate. *Remove one of the tiles with an orange brick separator.*

How to read info on the tiles:

- Element: the chemical element represented, which is determined by the # of protons
- Mass #: the total protons plus neutrons in the nucleus
- Abundance: the amount of a stable isotope found in naturally-occurring samples of this element
- Half-life: the time frame in which a radioactive (unstable) isotope has a 50% chance of decaying
- Tower height: number of bricks tall, related to extra energy per particle in the nucleus
- Decay type: the form of radioactive decay that this isotope will usually undergo e.g. stable, beta-minus, etc. (determines brick color)
- Binding energy: the amount of energy (in eV, electron volts) required to disassemble this nucleus into individual protons and neutrons



Figure 1. An isotope tile with stats.



Figure 2. Removing an isotope tile.

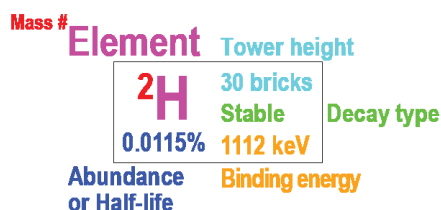


Figure 3. A legend for isotope tiles.

### Step 2 Assemble the Chart

Each tile has some information about that isotope, especially instructions for building its own LEGO tower. The color of brick is determined by whether it is a stable isotope or its kind of radioactive decay, while the height is listed in bricks. *Build your tower with the correct color and height, alternating direction each level for strength (see example towers). Attach your isotope tile on the top. Place your isotope tower on the chart plates in the correct row (element) and column (number of neutrons - you'll have to calculate that). If there are more unclaimed tiles left, build another tower!*

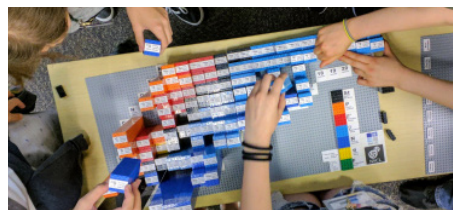


Figure 4. Assembling the chart.

### Step 3 Observation

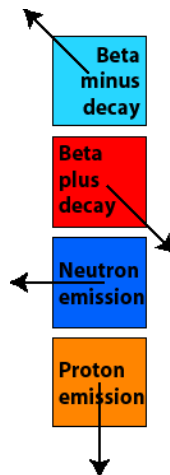
This Chart only contains the first ten elements - the full Chart would be 118 elements with >3000 isotopes! With one or more partners, *make some observations about the Chart you've built (write answers in the side column):*

- Which decay type is the most common? Which is least common?
- What pattern(s) can you find in where colors/decay types are located?
- How does the half-life change for isotopes farther away from stable?

- Aside from stable nuclei (which last forever), which two decay types tend to be the slowest (longest half-lives)? Which two are the fastest?
- What pattern(s) can you see in the tower heights (extra energy per particle)?
- How is the Binding Energy on an isotope tile related to its tower height?
- How does Binding Energy change for isotopes of a single element? Compare it between stable and unstable isotopes, and as you get farther from stability.
- Can you imagine/name isotopes of the first ten elements that do not appear on your Chart? Can you guess why they are missing?

Some more information about radioactive decay before you proceed:

- Beta-minus decay keeps all of the particles but changes a neutron to a proton – the resulting nucleus would be up one row and left one column. Beta-plus decay does the opposite, changing a proton to a neutron and creating a nucleus down one row and right one column. (see directions of change in the image at right)
- Nuclei with beta-decay types, plus stable nuclei, are considered “bound” - they may change but they keep the same number of protons + neutrons. “Bound” means it takes energy to remove those particles.
- Proton emission completely removes one proton from the nucleus, making a nucleus that is one element lower. Neutron emission releases a neutron, resulting in an isotope one column to the left.
- Nuclei that emit a proton or neutron are “unbound” – no energy is required to remove a particle, so they barely exist before decaying into something else. Any nuclei that would fall beyond the edges of the Chart may also be considered unbound. The edge between bound and unbound nuclei is called the “dripline”.



## Step 4 Model-building

What can you say about how nuclei work based on your observations?

Teaming up with one or more partners, *what “rules” can you guess at?*

- *Is there a pattern to which nuclei are stable and which are not? How does the relative number of protons and neutrons affect that?*
- *When a nucleus changes (e.g. by decay) to another with a shorter tower, what has changed about the extra energy in the nucleus? What must be released?*
- *In the sun, four hydrogen-1 nuclei fuse into one helium-4 nucleus and release a LOT of energy. Can you use the Chart to explain why that works?*
- *Based on the speeds (half-lives) of beta-plus/minus decays vs. proton/neutron emission, which do you think requires/releases more energy?*
- *Oxygen-13 decays to nitrogen-13, which decays to carbon-13. Look at the half-lives and extra energies (tower heights) of each. Can you suggest why some decays are faster than others?*
- *Look at the border between beta-minus decays and neutron emissions (light blue to dark blue). Is there anything interesting about the shape of the “dripline”? Some isotopes are bound when isotopes to their left and right are unbound - does it have anything to do with their number of neutrons?*
- *Look at where the beta-minus and beta-plus decays are on the Chart. After a long enough time and sufficient number of decays, what will those nuclei eventually wind up making? Why do they decay?*
- *Find the edges for bound nuclei. Are there more bound nuclei on the side with more neutrons than protons or vice versa? Put another way, do nuclei bind better with extra neutrons or protons? Any guesses why?*