**Beta** **Decay**

**Learning Target: Students will study the half-life of hydrogen-3, carbon-14, and a custom nuclide and the nature of their β- decay behavior.**

**Procedure**: Go to the PhET simulations at <http://phet.colorado.edu/simulations/> and choose “Chemistry”, “ Quantum Phenomena”, and Run the **Beta Decay** program.

1. Go to the “Single Atom” Tab. Hit the “Reset Nucleus” button. Observe the behavior of the tritium (hydrogen-3) nucleus carefully. Repeat this several times.
2. Hit the “Clear Chart” button. We will now conduct an experiment to determine the average half-life of hydrogen-3.
3. Hit “Reset Nucleus” and record in the table below the time it takes for the hydrogen-3 nuclide to decay.

Hydrogen-3

|  |  |
| --- | --- |
| **Trial** | **Decay Time** |
| **1** |  |
| **2** |  |
| **3** |  |
| **4** |  |
| **5** |  |
| **6** |  |
| **7** |  |
| **8** |  |
| **9** |  |
| **10** |  |

Carbon-14

|  |  |
| --- | --- |
| **Trial** | **Decay Time** |
| **1** |  |
| **2** |  |
| **3** |  |
| **4** |  |
| **5** |  |
| **6** |  |
| **7** |  |
| **8** |  |
| **9** |  |
| **10** |  |

1. Repeat the experiment at least nine more times, recording the decay time in the table, above.
2. Estimate the average time of decay (that is, the time it takes for 50% of the hydrogen 3 nuclei to decay.).\_\_\_\_\_\_
3. Compare your average result with someone else’s. Name \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Average \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
4. Why is your result and your partner’s slightly different?\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
5. Write the nuclear decay equation for hydrogen-3:\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
6. Repeat Steps 1 through 8 for carbon 14. The estimate for the average time of decay for carbon-14 is:\_\_\_\_\_\_\_\_\_
7. Write the nuclear decay equation for carbon-14:\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
8. Go to the “Multiple Atom” Tab, toggle the hydrogen-3 radionuclide, and place thirty nuclei on the screen by hitting the “Add 10” button three times.
9. When do you observe the count of hydrogen-3 and helium-3 to be equal? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

1. Toggle the carbon-14 radioisotope, and place thirty nuclei on the screen by hitting the “Add 10” button three times.
2. When do you observe the count of carbon-14 and nitrogen-14 to be equal?\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
3. What are the three quarks that make up the neutron? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
4. When the neutron-to-proton ratio is too high, beta decay provides a route to possible stability. A neutron decays to form a proton, an electron (beta particle), and an anti-neutrino.
   1. What is the quark makeup of the proton?\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

* 1. Based on the internal constituents of the neutron and the proton, what is really happening inside a nucleus as the nuclide decays by the emission of a beta particle and an anti-neutrino?

1. Hit the “Single Atom” Tab and toggle the “Custom” button under “Choose Nucleus”.
   1. Conduct several experiments and observe the results of the decays.
   2. Adjust the half-life and conduct several additional decay experiments.
2. Go to the “Multiple Atom” Tab and conduct at least three experiments with custom nuclides, each with different half-life. What general observation can you make about the number of remaining original nuclides over a set amount of time and its half-life?
3. Beta decay offers a route to nuclear stability when the neutron-to-proton ratio is high. When the opposite is true, that is, there is a high proton-to-neutron ratio, two possible reactions, linked to energy parameters, may occur: a positron emission (β+ emission) or an electron capture.

* 1. A positron, β+, an anti-lepton, is none other than the anti-electron, e+. **The positron decay decreases the atomic number by one, while the atomic mass remains the same.** An electron neutrino is ejected with the positron. In this case, a proton in the nucleus becomes a neutron.

* + 1. Write the nuclear reaction for beryllium-7 positron decay to lithium-7.

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* + 1. What quark is changing inside the proton? To what? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

* + 1. Once outside the nucleus, the positron rushes to encounter an electron and destroys itself, becoming a gamma ray. Why does this happen?
  1. The electron capture occurs when electrons from the atom’s first or second energy level (K-capture or L-capture, respectively) is captured by the nucleus, ejecting a neutrino. Rubidium-83 becomes Krypton-83 by electron capture. Write the nuclear reaction for the electron capture in rubidium-83.