Introduction* –

Radioactive nuclei disintegrate via different processes and at different rates. The amount of time required for different radioactive nuclei to decompose varies widely, from seconds or minutes for very unstable nuclei to a billion years or more for long-lived radioactive nuclei. Polonium-218, for example, emits alpha particles and decays very quickly – within minutes. Uranium-238 also decays via alpha-particle production, but the decay takes place over billions of years. The relative rate of decay of different radioactive isotopes is mostly conveniently described by comparing their half-lives. The half-life \( t_{1/2} \) of a radioactive isotope (called a radioisotope) is the amount of time needed for one-half of the atoms in a sample to decay. Every radioisotope has a characteristic half-life which is independent of the total number of atoms in the sample. Thus, the half-life of polonium-218 is about three minutes, while the half-life of uranium-238 is more than 4 billion years. Regardless of the total number of atoms in a sample of polonium-218, one-half of the atoms will always decompose to produce other atoms within three minutes.

Radioactive decay is a spontaneous and completely random process. There is no way to predict how long it will take a specific atom of a radioactive isotope to disintegrate and produce a new atom. The probability, however, that a specific atom will decay after a certain period of time can be simulated by studying other random processes, such as a coin toss or a “roll of the dice.”

The purpose of this activity is to simulate radioactive decay by studying the probability of a random process – rolling dice. The “radioactive decay” of dice will be studied by rolling 10 dice ten times in Round 1 and recording the number of dice that display a specific “decay number,” for example, all dice that read six. (Rolling 10 dice ten times is equivalent to rolling 100 dice once.) The total number of dice that “decayed” (landed on six) during Round 1 will then be counted and subtracted from the total number of dice rolled. This is the number of dice remaining that will be rolled in Round 2. This process will be repeated until no dice remain. The “half-life” of dice will be determined by graphing the number of dice remaining after each round.

Materials – 10 multi-sided dice

Procedure

1. Obtain a set of “multi-sided” dice. The “decay number” should be listed on the dice container (if it isn’t, ask the instructor for the number). Record the number of sides on the dice and the assigned decay number in the Data Table.
2. Roll all 10 dice. Hint: roll the dice so they all have an opportunity to have a “random” roll and all of the dice land flat. Re-roll any dice that do not land flat.
3. Assume that any dice landing on the assigned decay number have “decayed.” Record the number of dice that decayed in the Data column of the Data Table.
4. Repeat steps 2 and 3 until the 10 dice have been rolled 10 times (for a combined total of 100 dice rolls). After each roll, record the number of dice with the assigned decay number in the data column of the Data Table.
5. Add together the number of dice that decayed from the Data column. Enter this number – the total number of dice that decayed in the first round – in the “Number of dice that decayed” column of the Data Table.
6. Subtract the number of dice that decayed from the initial number of dice (100 for the first round) to determine the number of dice remaining. Record the “Number of dice remaining” in the Data Table and enter this number as the initial number of dice for the second round.

7. Repeat steps 2-6. Roll the dice as many times as needed to match the number of dice (initial) for Round 2. Record all data in the Data Table. For example, if 79 dice remain after the first round, then 10 dice would be rolled seven times and then nine dice would be rolled once so that the total number of dice rolled in Round 2 is equal to 79 [(10 \times 7) + 9 = 79].

8. Repeat step 7 until no dice remain or until 20 rounds of “radioactive decay” have been completed.

Data Analysis

1. Graph the results obtained for the “radioactive decay” of dice. Note: include a point on the graph for “100” as the number of dice “remaining” after zero rolls of the dice (Round zero); i.e. number of dice remaining vs. number of rounds.

2. Determine the half-life: Choose two points on the y-axis, where the first point is about twice as large as the second point (e.g. 80 dice ad 40 dice). How many rounds are needed for one-half of the dice to decay?

3. Compare the value of the half-life with that obtained by another group using the same-sided dice but a different “decay number.” Does the half-life depend on the “decay number” that was assigned? Explain, based on probability.

Post-lab Questions

1. Copper acetate containing $^{64}$Cu is used to study brain tumors. This isotope has a half-life of 12.7 hours. If you begin with 25.0ug of $^{64}$Cu, what mass is micrograms remains after 63.5 hours?

2. The oldest-known fossil found in South Africa has been dated based on the decay of Rb-87.

$$^{87}\text{Rb} \rightarrow ^{87}\text{Sr} + ^{0}_1\beta$$ \hspace{1cm} t_{1/2} = 4.8 \times 10^{10} \text{ years}$$

If the ratio of the present quantity of 87Rb to the original quantity is 0.951, calculate the age of the fossil.

3. The isotope of polonium that was most likely isolated by Marie Curie in her pioneering studies is polonium-210. A sample of this element was prepared in a nuclear reaction. Initially, its activity ($\alpha$ emission) was 7840 dpm. Measuring radioactivity over time produced the data below. Determine the half-life of polonium-210.

<table>
<thead>
<tr>
<th>Activity (dpm)</th>
<th>Time (days)</th>
</tr>
</thead>
<tbody>
<tr>
<td>7840</td>
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</tr>
<tr>
<td>7570</td>
<td>7</td>
</tr>
<tr>
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<td>14</td>
</tr>
<tr>
<td>5920</td>
<td>56</td>
</tr>
<tr>
<td>5470</td>
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</tbody>
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