Half-life of "Dice-ium"

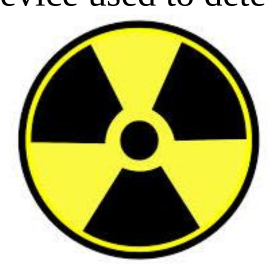
Background:

Radioactive decay and radiation is important to us for many reasons. It pervades our everyday lives in many ways. A few ways that radioactivity is important includes:

- ► advances in the scientific understanding of the nature of matter
- ► some medical treatments
- ► natural exposure to radioactive materials in rocks and soil
- ► scientific and archeological use for dating of materials
- ► disposal of radioactive waste used in power plants, medical facilities, and weapons
- ► threat of the potential use of "dirty bombs" by terrorists
- ► irradiation of food

The nuclei of elements heavier than iron (atomic number of 26) are relatively massive and require more energy to hold them together. Unstable atoms are said to be ***radioactive*** because spontaneously decay into different nuclei and emit particles which we call ***radiation***. Many elements have isotopes whose nuclei are unstable. All atoms with an atomic number of 84 (polonium) or greater are unstable.

For a large sample of a particular radioactive material, the ***rate*** at which decays occur is dependent upon the stability of the nuclei and the number of un-decayed nuclei. The rate at which decay occurs is known as ***activity***. For a given sample of radioactive material, the more un-decayed nuclei there are, the greater the activity. An activity of 3.7×10^{10} decays/second is defined to be 1.0 curie. This unit was named after Marie Curie, an early investigator of radioactivity and the winner of two Nobel Prizes. A Geiger counter (named after its inventor, Hans Geiger) is a device used to detect and measure the radiation emitted by unstable nuclei.



Although all individual nuclei of a radioactive element are unstable, not all of them decay at the same time. The probability of decay of a nucleus is dependent upon the nucleus' stability, but **NOT** on its past history or present physical conditions (e.g. temperature, pressure). This results in random decay of nuclei within a large sample of identical unstable nuclei. Some nuclei decay quickly and some take longer. There is no single time at which all nuclei decay.

The concept of ***half-life*** refers to the amount of time required for a radioactive sample to have half of the nuclei decay. This concept applies to each of the following:

- Half-life is the time for ½ of the nuclei to decay
- Half-life is the time for the mass of an original sample to drop to ½ of its original value
- Half-life is the time for the activity to drop by 50%

Experiment #1 – Half-life of "Pennyium"

Purpose: To determine the 'half-life' of coins being tossed

Procedure:

Gather a large number of pennies and place them in a shaker. Each penny represents a nucleus of an atom. Pick one face (tails?) to indicate a decay if it faces upward after the toss. "Heads" mean that the nuclei did not decay. Shake the pennies in a container and toss them onto a table. Count and record the total number of pennies (the ones that don't decay) remaining. Also record the total number of decayed nuclei produced. Remove the pennies that decayed, and put the pennies that didn't decay back in the container for another shake and toss. Repeat this procedure until you have tossed at least 12 times or until there are fewer than 4 pennies remaining.

Analysis:

Plot a graph of the population of un-decayed nuclei and the decayed nuclei as a function of time (time will be measured by penny tosses).

Q1: Based upon your graph, what is the half-life of 'pennyium nuclei'? Explain your reasoning!

Q2: Based on the laws of probability, what should you have expected for the half-life of pennyium?

Experiment #2 – Half-life of "Diceium"

Purpose: To determine the 'half-life' of ordinary, six-sided dice ("diceium").

Estimation: Without doing any probability calculations, estimate what you think the half-life of 'diceium' is if one particular number facing upward means decay.

Procedure: Gather a large number of dice and place them in a shaker. Each die represents a nucleus of an atom, and time will be represented by the number of dice throws. Pick one number (3?) to indicate a decay if that number faces upward. The other numbers mean that the nuclei did not decay. Roll the dice, and record in a data table how many original nuclei there are and how many decay as a function of time (again, time will be measured in dice throws). Remove the dice that decayed, and put the un-decayed dice back in the container for another shake and throw. Repeat this procedure until you have rolled at least 12 times or until there are fewer than 4 dice remaining.

Analysis:

Plot a graph of the population of un-decayed diceium and the population of decayed diceium as a function of time.

Q1: What is the half-life of 'diceium'? Explain your reasoning!

Q2: About what percent of the original diceium remains un-decayed after a time of 6 dice rolls?

Q3: About what percent of the original diceium remains un-decayed after a time of 2.5 dice rolls?

Q4: Does the experimental value of half-life that you determined in Q1 agree with a theoretical value based on your knowledge of the laws of probability for 6-sided dice? Explain.

Experiment #3 – Half-life of "Tackium"

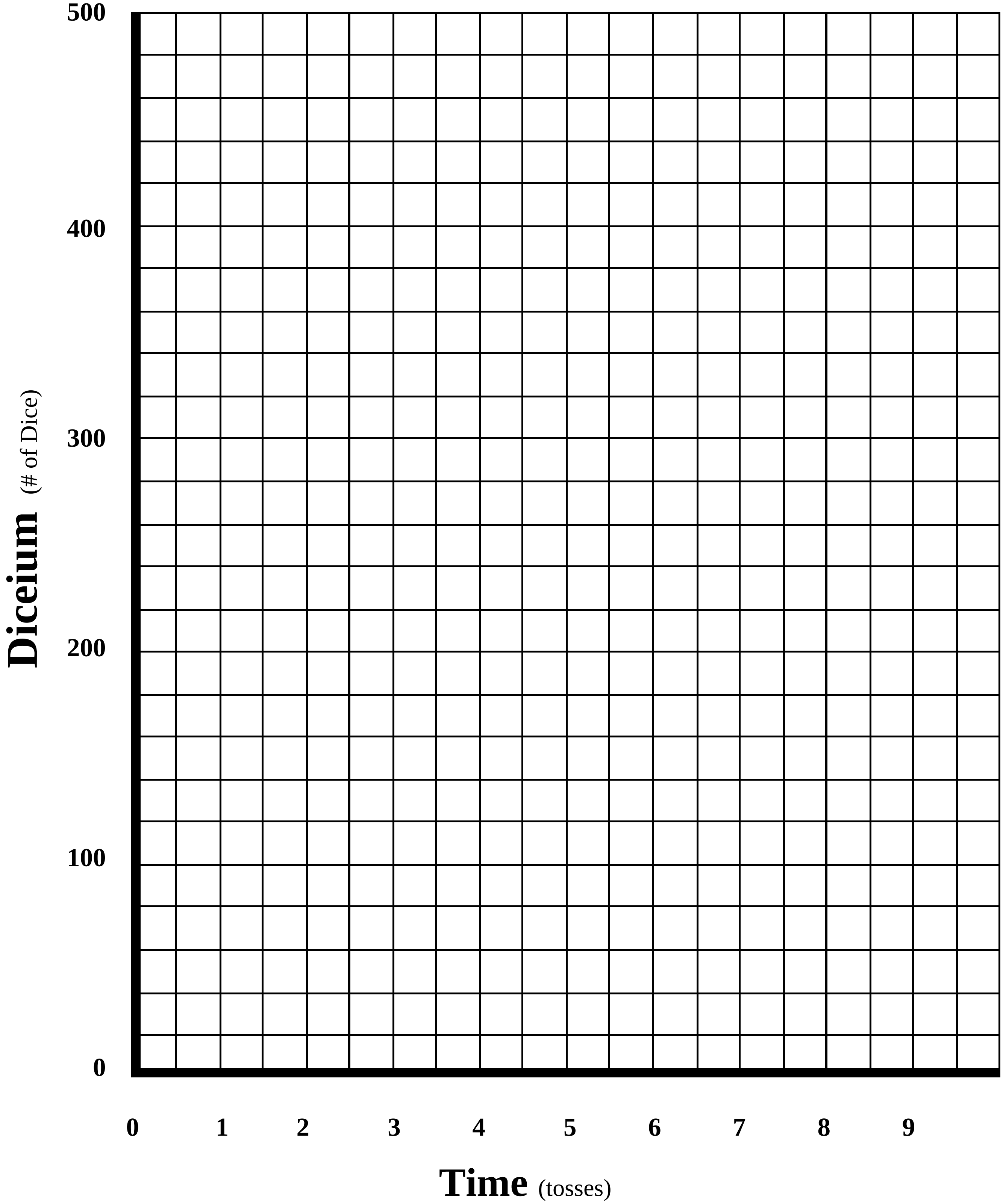
Background: An ordinary thumbtack has a round, curved top and a shaft with a point at the end. If you toss one onto a hard surface, there are two possible ways it can land. It can land on its "side" (both the sharp point and the edge of the round top are touching the surface) or it can land on its "back" (the sharp point is pointing straight upward).

Estimation: Without doing any probability calculations, estimate what you think the half-life of 'tackium' is if the sharp point facing upward means decay.

Purpose: To determine the half-life of 'tackium'.

Procedure: Design your own procedure.

Analysis: Present your findings in a clear and convincing manner.


500
400
300
200
100
0
Diceium (# of Dice)
0
1
2
3
4
5
6
7
8
9
Time (tosses)