INVESTIGATION 1

WHAT IS RADIOACTIVITY?

INTRODUCTION

The study of probability allows us to make predictions about the occurrence of certain events such as birth, death, and accident rates, and in this case, the breakdown of atomic nuclei during the radioactive decay process. Radioactivity is emitted when particles or energy rays are given off by an atom's nucleus (See Figure 1). Three different kinds of radiation can be given off: alpha, beta, or gamma (Figure 2). During this “decay” process, the element spontaneously gives off particles or energy rays, known as radiation. Radon-222 (^{222}Rn) is the direct product of the decay of the most common radium isotope, radium-226. Radium is a product, several steps removed, of the decay of the most abundant uranium isotope, uranium-238. Radon-222 breaks down into its decay product isotopes, polonium-218, among others. Decay product isotopes are sometimes referred to as progeny or daughters.

Each element has a characteristic average rate of decay that doesn't change. The time it takes for one-half of the atoms in a given radioactive sample to decay is called the half-life of that isotope. Each radioactive isotope has its own unique half-life, which is totally unaffected by temperature, pressure, and other factors. **In this exercise you will conduct an investigation that simulates radioactive half-life and its relationship to statistical probability.**

OBJECTIVE

To apply the process of probability to the concepts of radioactive decay and radioactive half-life.

MATERIALS

• One large bag of m&m’s (plain)

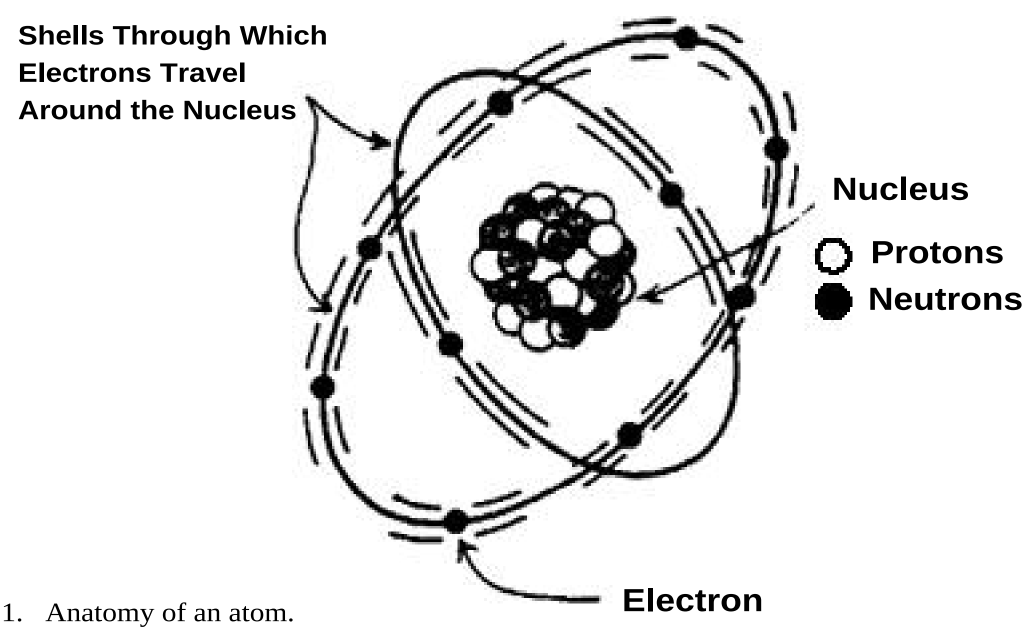

Figure 1. Anatomy of an atom.

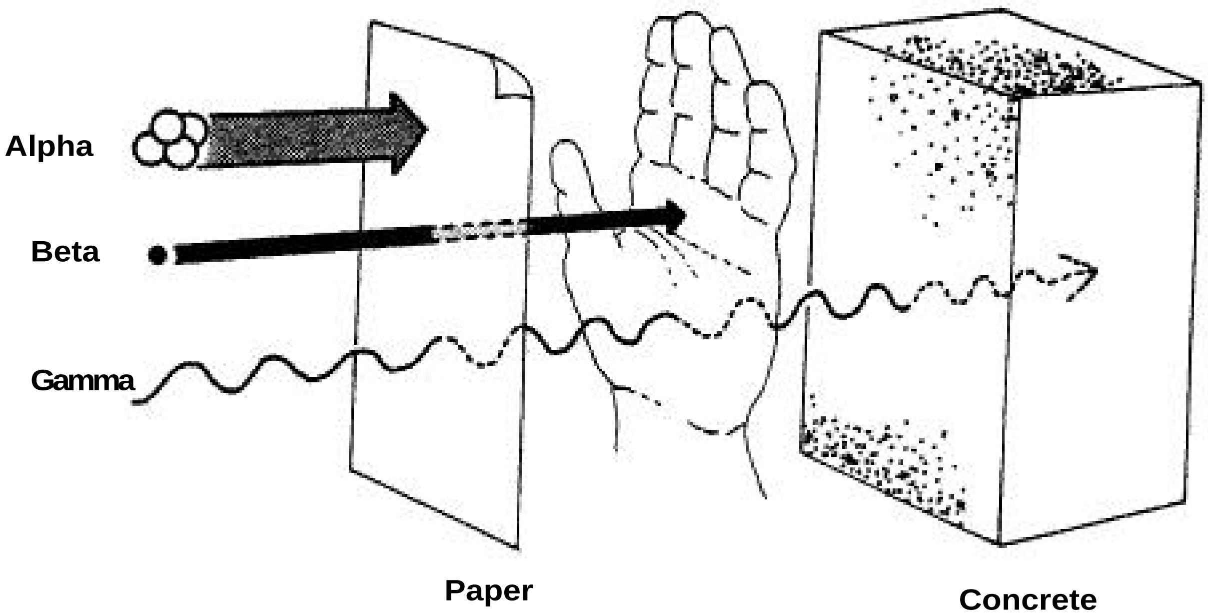

Figure 2. Penetrating power of radiation. Alpha particles are relatively large, but are easily stopped by a piece of paper or a layer of skin. Beta particles are much smaller, travel at high speed, and can penetrate the skin. Gamma radiation has no mass, travels at the speed of light, and can go right through the body.

PROCEDURE

Note: Each m&m in the bag represents a radioactive atom. An atom decays and emits its radioactivity when the side marked "m" turns up. It is removed from the pile before the next roll.

1. Begin by rolling all m&m's (atoms). You may eat some, but be sure to begin the procedure with at least 100 atoms. Eat the yellow ones; it is hard to see the "m" on them! Remove any atoms that decay (the side marked "m" turns up). Record your results in table format.

2. Continue rolling all active atoms until all of them have decayed.

3. Do you think the results would be exactly the same if you rolled the radioactive atoms again? Why or why not?

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DATA COLLECTION

4. Make at least five trials, each time starting with a full bag of radioactive atoms. As in Step 1, roll the radioactive atoms repeatedly until they have all decayed into a new isotope.

5. Use a spreadsheet to enter the data from your experiment for each of the five trials.

6. Plot an X/Y graph of your data, using a spreadsheet. If spreadsheet software is not available, you can plot the data by hand.

   Note: The half-life of a radioactive substance is the time it takes for half of the atoms to decay.

ANALYSIS

7. How many rolls were necessary (on average) before half of the atoms decayed?

   Note: Each roll represents one half-life for your m&m's.

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8. How many half-lives were necessary (on average) before 3/4 of the atoms decayed?

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   Explain why you obtained this result, in terms of the definition of half-life.

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9. How many *additional* rolls do you think it would take to deplete the pile if your starting pile was twice as large?

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10. Perform several trials to check your prediction.

11. You are given 10 grams of pure uranium-238 (^{238}U) on January 1. Its half-life is 4 1/2 billionyears, and it decays to form thorium-234 (^{234}Th).

    a) How long would you have to wait before half of it turned into thorium-234?

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    b) How much would you have left after 9 billion years? ______________

    c) How long would you have to wait before you had only 1/2 g left?
    Hint: Use graphing techniques to approximate the length of time.

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CONCLUSIONS

12. In your own words, explain the half-life of an element.

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13. Why do you think half-life is an important concept in the study of radon?

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