# RADIOACTIVITY (Half-Life)

## PROBLEM PRESENTATION / EXPLORATION

A. Most of you like to spend money. Lets investigate how long it would take to spend a million dollars. You probably think that this would not be much of a problem, right? There is only one rule we will follow in this exercise. **On each day you can only spend half of what you start the day with.** So on the first day you get to spend a half million dollars.

1. Question: "If on January 1 you start with one million dollars, on what day will you end up with only one dollar or less?
2. Estimate how long you think it will take to spend the million dollars: two days? a week? a month? a year? ten years?
3. The following table may help in figuring out how long it would take.

| Date | Starting Amount | Ending Amount |
|---|---|---|
| Jan. 1 | 1000000.00 | 500000.00 |
| Jan. 2 | 500000.00 | 250000.00 |
| Jan. 3 | 250000.00 | 125000.00 |
| Jan. 4 | 125000.00 | 62500.00 |
| Jan. 5 | 62500.00 | 31250.00 |
| Jan. 6 | 31250.00 | 15625.00 |
| Jan. 7 | 15625.00 | 7812.50 |
| Jan. 8 | 7812.50 | 3406.25 |
| Jan. 9 | 3406.25 | 1703.12 |
| Jan. 10 | 1703.12 | 851.56 |
| Jan. 11 | 851.56 | 425.78 |
| Jan. 12 | 425.78 | 212.89 |
| Jan. 13 | 212.89 | 106.44 |
| Jan. 14 | 106.44 | 53.22 |
| Jan. 15 | 53.22 | 26.61 |
| Jan. 16 | 26.61 | 13.30 |
| Jan. 17 | 13.30 | 6.65 |
| Jan. 18 | 6.65 | 3.32 |
| Jan. 19 | 3.32 | 1.66 |
| Jan. 20 | 1.66 | .83 |

4. According to the above table, on Jan. 20 you would end up with less than one dollar.
5. How long do you think it would take you to spend one hundred dollars following the same rule?

| Date | Starting Amount | Ending Amount |
|---|---|---|
| Jan. 1 | 100.00 | 50.00 |
| Jan. 2 | 50.00 | 25.00 |
| Jan. 3 | 25.00 | 12.50 |
| Jan. 4 | 12.50 | 6.25 |
| Jan. 5 | 6.25 | 3.12 |
| Jan. 6 | 3.12 | 1.56 |
| Jan. 7 | 1.56 | .78 |

6. In both of these cases we would say that the time it took to spend half of what remained was one day. We might call this the "half-life."

**CLASS RESPONSE / CONCEPT INVENTION**

A. In the exploration activity above, the time to use up half of the money was imposed on you for the exercise (one day). We would now like to determine what this "half-life" for some other activity is experimentally.

B. Isotopes of various atoms undergo a totally random phenomenon known as radioactive decay. One can not predict when any single atom will undergo decay, however, for a large number of atoms the "half-life" can be determined. **The "half-life" is the amount of time that it would take for half of the atoms we start with to undergo their random decay**.

C. We want to experimentally determine how long it would take for an imaginary isotope to have half of its atoms decay. We will simulate atoms by using partially colored sugar cubes.

D. Preparation of "ORANGIUM", "GREENIUM," and "BLUIUM".

1. Obtain approximately 1500 sugar cubes.
2. With an orange magic marker color one face of each of 500 sugar cubes orange.
3. With a green magic marker color two faces of each of another 500 sugar cubes green.
4. With a blue magic marker color three faces of each of another 500 sugar cubes blue.
5. Place all the "ORANGIUM" "GREENIUM", and "BLUIUM" isotopes into three separate large Ziploc bags. (If the sugar cubes are stored in a sealed Ziploc bag, they can be used for many years. If left open to the air, the sugar will absorb moisture from the air and become sticky.)

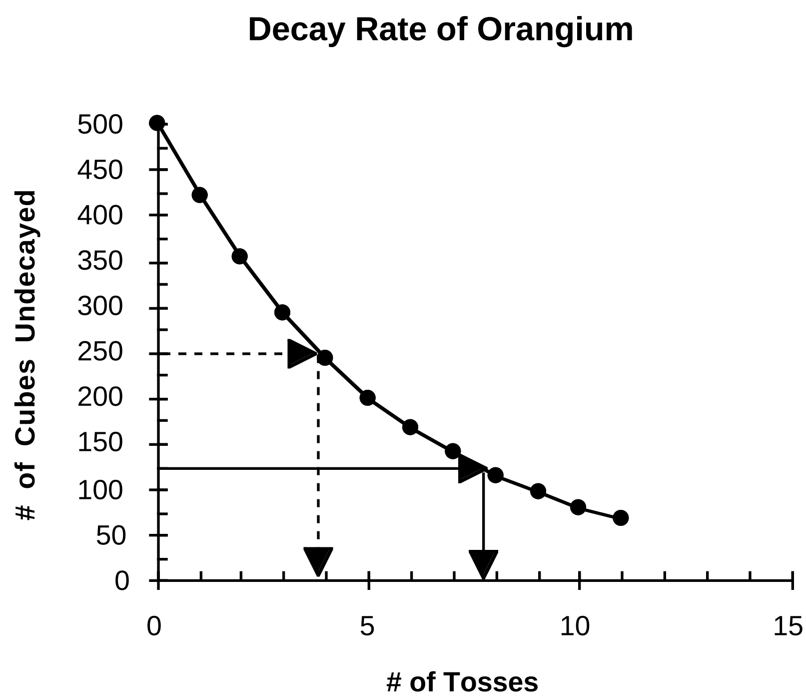
E. Directions

1. Have a group of students toss from the bag all of the orange sugar cubes onto the table. Insure that they are lying flat on the surface of the table.
2. Separate into two piles those that landed with an orange face up and those that landed with a white face up.
3. Record the number of each in the table below. Each cube that lands with an orange face up represents an atom that has decayed.
4. Set aside all the cubes that landed with an orange face up. Gather up all those that landed with a white face up and put them back in the bag. In your second toss use only these atoms in the bag.
5. Repeat this process for a total of eleven tosses. Mythical data are plotted below.

| Toss # | # White Cubes After Toss | # Orange Cubes After Toss | Cumulative # of Orange Cubes |
|---|---|---|---|
| 0 | 500 | 0 | 0 |
| 1 | 422 | 78 | 78 |
| 2 | 354 | 68 | 146 |
| 3 | 294 | 60 | 206 |
| 4 | 243 | 51 | 257 |
| 5 | 200 | 43 | 300 |
| 6 | 167 | 33 | 333 |
| 7 | 140 | 27 | 360 |
| 8 | 115 | 25 | 385 |
| 9 | 96 | 19 | 404 |
| 10 | 80 | 16 | 420 |
| 11 | 67 | 13 | 433 |

Total # of Cubes 500

6. Plot the data from the experiment on a piece of graph paper. Label the vertical axis # Cubes Undecayed (white cubes), and label the horizontal axis # of Tosses.




7. Read from the graph the "half-life" of "ORANGIUM" (the number of tosses it took for half of the total cubes to come up with an orange face.)
[If the total # of cubes was 500, then how many tosses did it require for 250 of them to come up with an orange face? On the y-axis find 250; draw a line horizontal to the x-axis (the dotted line) starting at 250 and stopping when it reaches the curve. Now starting at this point on the curve, draw a line parallel to the y-axis (dotted line) until it crosses the x-axis. Read how many tosses it says it took to have 250 cubes come up with an orange face. Does this match up with how many throws it took? Check your data table. According to our mythical data the graph would indicate that about 3.8 tosses would be required to have 250 of the cubes come up with an orange face. If we look at the table we see that after three tosses 206 of them had come up orange. After four tosses 257 had come up orange. Roughly this corresponds to about 3.8 tosses being required to use up half of the cubes.]
8. If it takes 3.8 tosses to use up 250 of the cubes, one-half of what started out with, how long would it take to use up half of the 250? (This is asking the same thing as in part G below, except that we have the data on the graph to check it. Notice that another line parallel to the x-axis has been drawn from 125 on the y-axis and where this crosses the curve another line parallel to the y-axis has been dropped. This line crosses at about 7.7. The difference between 7.7 and 3.8 is about 3.9. This means that it took about 3.9 tosses to reduce the 250 cubes down to 125. In other words the half life (about 3.8 or 3.9 tosses) remains the same. Therefore it would take about 3.8 or 3.9 more tosses to reduce the 125 cubes down to 63 cubes. If you have time, do it with the cubes to check it out.

F. Carry out the determination of the "half-life" for "GREENIUM" and "BLUIUM" in a similar manner. Do all three isotopes have the same "half-life"? [No.]

G. What would the "half-life" be if you used 2000 "atoms" of "ORANGIUM"? Have students predict. Would it be four times as long, since you started with four times as many "atoms"? Would it be one fourth as long? [The "half-life" will not change. It is not dependent upon the number of atoms you start with. We saw that to some extent in number 8 above.]

H. Hopefully the students can draw the conclusion that the half-life is not dependent on the initial quantity. This is not to be confused with the Exploration Activity where the "half-life" was imposed on the exercise.

I. Many naturally occurring processes in this universe other than radioactive decay proceed in a manner similar to that illustrated by the sugar cube isotopes. A very common example of this is water draining out of a buret. Just as the rate of sugar cubes coming up with a colored face was directly proportional to the number of cubes left, the rate of water draining out of the buret is directly proportional to the volume of water left in the buret. [The more water in the buret, the faster it drains; the lesser amount in the buret, the slower it drains.]

J. Can we find the "half-life" of the water draining from a buret in an analogous way to our determination of the "half-life" of the sugar cube isotopes?

1. Fill a buret with water. Let it drain through the tip until all the air is forced out. Allow it to drain down to the 50.0 mL mark [The stopcock must be wide open when the water is draining out.]
2. Place a 10 mL graduated cylinder beneath the tip of the buret and allow all the water below the 50.0 mark to drain out into the graduated cylinder. RECORD THIS VOLUME. It is important that all the water beneath the 50 mL mark be measured. You might have to apply some positive pressure on the mouth of the buret to blow the water out.
3. Refill the buret with water and drain through the tip until all the air is forced out. Add more water if needed so that the water level can be drained down to the 0.0 mL mark.
4. Open the stopcock all the way to start the water flowing. Measure the time needed for the water to drain to the 10 mL, 20 mL, 30 mL, 40 mL, and 50 mL marks. The best results probably occur when one person watches the falling level and calls out to the second person who is watching the clock and recording the times.
5. Repeat step #4 to check on the times to hit each of the marks. Average the two times and enter these times in the average time column.
6. When filling in the table, note that the "Vol Remaining" equals TOT VOL - Buret Reading. (TOT VOL = 50.0 mL + Volume you found in step #2)
7. Plot the data from the experiment on a piece of graph paper. Label the vertical axis Vol Remaining [This is just like the sugar cube graph.] Label the horizontal axis Time.