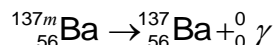
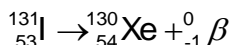
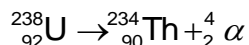


#31 Half-life of Ba-137m

Purpose The half-life of Ba-137m is measured using a Geiger counter interfaced with LabQuest.

Introduction

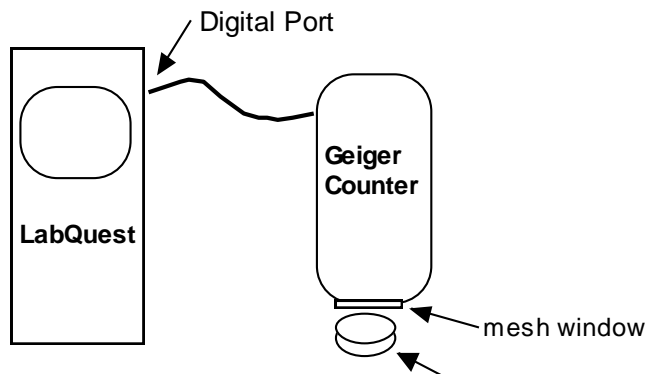
Radioactive elements emit alpha, beta or gamma radiation to become a new element or a new isotope of the same element. Alpha particles, α , are helium nuclei which have a charge of +2 and a mass number of 4. Beta minus particles, β , are electrons with a charge of -1 and a mass number of 0. Gamma, γ , is electromagnetic radiation similar to x-radiation, and thus has 0 mass and 0 charge. The 'm' in isotopes which decay by emitting γ , such as Ba-137m, means metastable. Examples of nuclear equations for each type of decay mode are given below. Notice that the masses and charges balance; the mass (and charge) on the left must be the same as the mass (and charge) on the right. The identity of a new element formed is found from its charge, which is the atomic number of the element.



The rate of radionuclear decay is measured in terms of its *half-life*, $t_{1/2}$, the length of time necessary for *one half* of a given mass of radioactive isotope to decay to products. For example the half-life of U-238 is very long, more than 5 trillion years and for I-131, about 8 days. You will measure $t_{1/2}$ for Ba-137m in this experiment.

Apparatus

A Geiger counter (right) interfaced with LabQuest is used to monitor radiation. The Geiger counter contains a tube of argon gas, Ar, and a thin mica window. Alpha, beta or gamma radiation entering the mica window ionizes the Ar forming an "ion pair" which consists of an argon cation, Ar^+ , and an electron. When ion pairs are produced an electric circuit is completed and clicks or counts can be detected. The number of counts per minute, cpm, measures the quantity of radioactivity. The planchette holds the radioactive sample.



Safety and Waste Disposal

Normal safety precautions are taken, that is, safety glasses and gloves should be worn throughout this experiment. The amount of radioactive material used is extremely small. The Cs/Ba-137m isotope generator is *exempt* from federal or state licensing and requires no special handling, storage or disposal requirements. The Ba-137m isotope decays to practically zero activity within 15 minutes. Liquid exempt products such as this can be discarded in the sink. Gloves and paper towels may be thrown into normal trash containers.

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Procedure

Part A. Setting up the LabQuest/Radiation Monitor

1. Plug in LabQuest. Turn it on. Connect monitor to a Digital port on the side of LabQuest.
2. Turn on the radiation monitor. Set the range switch to BATT. If the meter pointer doesn't indicate within the battery section on the scale, notify your instructor. After checking the battery, set the range switch to the x10 position and set the function switch to AUDIO.
3. Position the radiation monitor so that the mica window is next to the planchette. Select **Sensors** from top menu bar, then choose **Sensor Setup**. Select correct Digital Channel 1 (or 2). Select **Radiation Monitor** from the drop-down menu. Press **OK**. Select **Chart** icon on top right. Start the count by selecting the **Collect** button (half-circle) on the bottom left. (Red square appears on button). The chart will plot radiation in counts per minute (cpm) vs. time in seconds. Now you are ready to take data.

Part B. Measuring Background Radiation

1. Collect the data for approximately 100 seconds.
2. Stop the count by pressing red **Collect** button. Go to data table (top menu) , record values on your data sheet and take an average of the readings. Round to the nearest count. This value will be subtracted from future readings.

Part C. Half-life of Ba-137m

1. Return to **Chart** mode.
 2. Wait until your instructor is in position to add the Ba-137 to the planchette. Press **Collect** button. A message window opens. Select **Discard** (bottom left). Your instructor will deposit a small amount (5-10 drops) of the Ba-137m into your planchette. Data will automatically be plotted on the chart. (Note that the data is sampled every ten seconds.) Collect the data for 600 seconds.
 2. When collection is done, stop the count by pressing red **Collect** button. Go to data table (top menu) , record **Time (seconds)** and **Radiation (Counts)** onto your data/results table. Subtract the background reading from this value; record result in the corrected column of the data table.
 3. *Determining the half-life using your tabulated data:* Take all cpm values needed below from the *corrected* cpm column in your table.
 - a) Find the largest cpm reading from the data table. Record the time in seconds for that reading.
 - b) Divide this cpm reading by 2. Find the corrected cpm value from your data which is closest to this reading. Record the corresponding time. In most cases you will have to estimate the time.
 - c) Find the time difference between the largest cpm and the cpm/2 reading. This is the half-life of Ba-137m in seconds.
 4. *Determining the half-life using a plot of corrected counts vs. time (s):*
Plot the counts on the y axis and time on the x-axis. Make sure that the corrected radiation count points are drawn as vertical error bars to reflect the uncertainty in the readings. To find the half-life, select a reading and its corresponding time, then the half-reading and its time. The difference in times is the half-life.
- Data and Results** (Half-Life Ba-137m)

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Calculating the half-life from your data

1. Largest cpm _____ Time (#1) _____ s
 2. Largest cpm/2 _____ Time (#2) _____ s (Estimate if necessary)
 3. Time (#1) - Time (#2) _____ s
- $t_{1/2}$ B-137m _____ s
- $t_{1/2}$ Ba-137m _____ min

Questions

1. At the beginning of the experiment it is emphasized that you must wear gloves, yet you are allowed to dispose of material in the sink and trash can. Explain.
2. The Ba-137m used in this experiment is generated from Cs-137. What is the decay mode for Cs-137, that is, what kind of particles does it emit? Write a nuclear equation for this process.
3. In nuclear decay reactions the half-life does not depend upon the amount of material present. Therefore, you can determine the half-life by choosing any starting reading. Repeat the calculation of $t_{1/2}$ for Ba-137m starting with a reading other than the largest one recommended in the experiment.

Instructor's Guide
(#31 *Half-life Ba-137m*)

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Time: 1 h

Equipment and Materials: per group unless otherwise indicated

| Items | Am't/group | Comment |
|-----------------------|--------------|---|
| Isotope generator kit | 1/class | Contains Isotope exchange column, 250 mL eluting solution, syringe, planchettes |
| Radiation Monitor | 1 | 4/4EC Includes interface cable |
| LabQuest | 1 | |
| Gloves | 1 pr/student | |
| Safety glasses | 1 pr/student | |

Generating Ba137m:

To generate Ba-137m, draw approximately 5 mL of eluting solution into the syringe. Remove top and bottom caps from the isotope exchange column. Insert the syringe into the top port on the exchange column. Position the bottom port of exchange column over the planchette.

Depress plunger on syringe to force approximately 5-10 drops through the column into the planchette. (number of drops is not critical but faster is better than slower)

Before depositing the Ba-137m into the planchette, the instructor should check the positioning of the planchette in relation to the radiation detector. (should be as close to the mica window as possible without touching)

Before depositing the Ba-137m into the planchette, the instructor should also check to see if the setup instructions have been followed and that the student has clicked on the **Collect** icon. (it's okay to have several background readings before introducing the Ba-137m into the planchette.)

Ideas/Information

1. A *planchette* is a flat piece of metal; especially, a disk of metal ready to be stamped as a coin. Radiation monitors that contained slots for the planchettes are no longer available.

2. Since nuclear decay is first order, the half-life does not depend on concentration. Thus any value can be taken as the starting reading in this experiment.

Typical Data and Results

Part B. Measuring Background Radiation

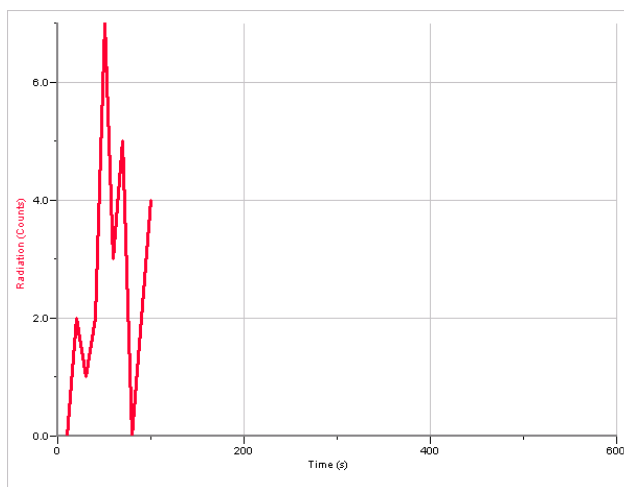
| | | | | | | | | | | |
|-----------------|----|----|----|----|----|----|----|----|----|-----|
| Time (s) | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100 |
| Radiation (cpm) | 0 | 2 | 1 | 2 | 7 | 3 | 5 | 0 | 2 | 4 |

Average counts: 2.6 rounded to 3

| | Latest | |
|----|----------|--------------------|
| | Time (s) | Radiation (Counts) |
| 1 | 10.0 | 0 |
| 2 | 20.0 | 2 |
| 3 | 30.0 | 1 |
| 4 | 40.0 | 2 |
| 5 | 50.0 | 7 |
| 6 | 60.0 | 3 |
| 7 | 70.0 | 5 |
| 8 | 80.0 | 0 |
| 9 | 90.0 | 2 |
| 10 | 100.0 | 4 |
| 11 | | |
| 12 | | |
| 13 | | |
| 14 | | |
| 15 | | |
| 16 | | |
| 17 | | |
| 18 | | |
| 19 | | |
| 20 | | |
| 21 | | |
| 22 | | |
| 23 | | |
| 24 | | |
| 25 | | |
| 26 | | |
| 27 | | |

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Data Table and Plot for Background. Similar (but not identical) to the ones in LabQuest.

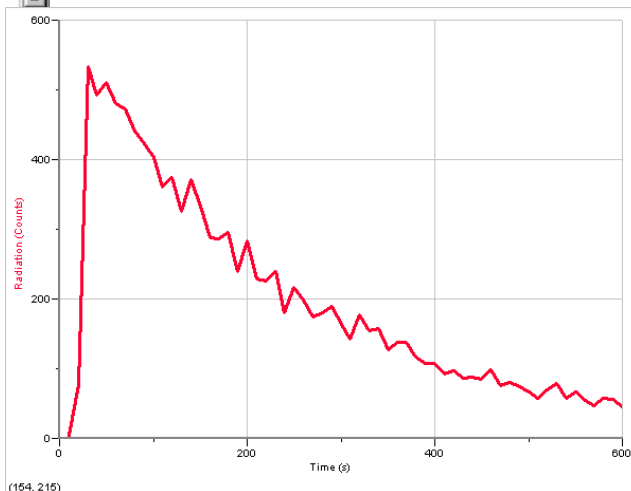


Part C. Half-life of Ba-137m (only 46 times below; room for 60 in table in Data/results)

| Time (s) | counts/min cpm | corrected cpm | Time (s) | counts/min cpm | corrected cpm |
|----------|----------------|---------------|----------|----------------|---------------|
| 10 | 6 | 3 | 240 | 181 | 178 |
| 20 | 78 | 75 | 250 | 216 | 213 |
| 30 | 534 | 531 | 260 | 198 | 195 |
| 40 | 493 | 490 | 270 | 174 | 171 |
| 50 | 511 | 508 | 280 | 180 | 177 |
| 60 | 480 | 477 | 290 | 189 | 186 |
| 70 | 473 | 470 | 300 | 163 | 160 |
| 80 | 441 | 438 | 310 | 143 | 140 |
| 90 | 422 | 419 | 320 | 177 | 174 |
| 100 | 403 | 400 | 330 | 154 | 151 |
| 110 | 361 | 358 | 340 | 158 | 155 |
| 120 | 374 | 371 | 350 | 128 | 125 |
| 130 | 325 | 322 | 360 | 138 | 135 |
| 140 | 371 | 368 | 370 | 138 | 135 |
| 150 | 334 | 331 | 380 | 117 | 114 |
| 160 | 288 | 285 | 390 | 108 | 105 |
| 170 | 286 | 283 | 400 | 108 | 105 |
| 180 | 295 | 292 | 410 | 93 | 90 |
| 190 | 239 | 236 | 420 | 97 | 94 |
| 200 | 283 | 280 | 430 | 86 | 83 |
| 210 | 229 | 226 | 440 | 88 | 85 |
| 220 | 226 | 223 | 450 | 85 | 82 |
| 230 | 239 | 236 | 460 | 99 | 96 |

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| | Latest | | | Latest | | | Latest | |
|----|----------|--------------------|----|----------|--------------------|----|----------|--------------------|
| | Time (s) | Radiation (Counts) | | Time (s) | Radiation (Counts) | | Time (s) | Radiation (Counts) |
| 1 | 10 | 5 | 27 | 270 | 174 | 35 | 350 | 128 |
| 2 | 20 | 78 | 28 | 280 | 180 | 36 | 360 | 138 |
| 3 | 30 | 534 | 29 | 290 | 189 | 37 | 370 | 138 |
| 4 | 40 | 493 | 30 | 300 | 163 | 38 | 380 | 117 |
| 5 | 50 | 511 | 31 | 310 | 143 | 39 | 390 | 108 |
| 6 | 60 | 480 | 32 | 320 | 177 | 40 | 400 | 108 |
| 7 | 70 | 473 | 33 | 330 | 154 | 41 | 410 | 93 |
| 8 | 80 | 441 | 34 | 340 | 158 | 42 | 420 | 97 |
| 9 | 90 | 422 | 35 | 350 | 128 | 43 | 430 | 86 |
| 10 | 100 | 403 | 36 | 360 | 138 | 44 | 440 | 88 |
| 11 | 110 | 361 | 37 | 370 | 138 | 45 | 450 | 85 |
| 12 | 120 | 374 | 38 | 380 | 117 | 46 | 460 | 99 |
| 13 | 130 | 326 | 39 | 390 | 108 | 47 | 470 | 76 |
| 14 | 140 | 371 | 40 | 400 | 108 | 48 | 480 | 81 |
| 15 | 150 | 334 | 41 | 410 | 93 | 49 | 490 | 75 |
| 16 | 160 | 288 | 42 | 420 | 97 | 50 | 500 | 66 |
| 17 | 170 | 286 | 43 | 430 | 86 | 51 | 510 | 58 |
| 18 | 180 | 295 | 44 | 440 | 88 | 52 | 520 | 69 |
| 19 | 190 | 239 | 45 | 450 | 85 | 53 | 530 | 79 |
| 20 | 200 | 283 | 46 | 460 | 99 | 54 | 540 | 58 |
| 21 | 210 | 229 | 47 | 470 | 76 | 55 | 550 | 67 |
| 22 | 220 | 226 | 48 | 480 | 81 | 56 | 560 | 54 |
| 23 | 230 | 239 | 49 | 490 | 75 | 57 | 570 | 47 |
| 24 | 240 | 181 | 50 | 500 | 66 | 58 | 580 | 58 |
| 25 | 250 | 216 | 51 | 510 | 58 | 59 | 590 | 56 |
| 26 | 260 | 198 | 52 | 520 | 69 | 50 | 600 | 46 |
| 27 | | | 53 | | | 51 | | |



Data Tables and Plot of cpm vs. time for Ba-137m sample for Part C (looks similar, but not identical to LabQuest)

Calculating the half-life from your data All cpm values below are corrected.

1. Largest cpm 530 Time (530) 30 s

2. (Largest cpm)/2 265 Time (265) 185 s (Estimate if necessary)

3. Time (530) - Time (265) = 155 s

$t_{1/2}$ Ba-137m 155 s

$t_{1/2}$ Ba-137m 2.58 min

Literature value 2.55 min

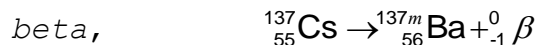
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Questions

1. At the beginning of the experiment it is emphasized that you must wear gloves, yet you are allowed to dispose of material in the sink and trash can. Explain.

The half-life of Ba-137m is so short that that the sample will be water by the end of the experiment.

2. The Ba-137m used in this experiment is generated from Cs-137. What is the decay mode for Cs-137, that is, what kind of particles does it emit? Write a nuclear equation for this process.



3. In nuclear decay reactions the half-life does not depend upon the amount of material present. Therefore, you can determine the half-life by choosing any starting reading. Repeat the calculation of $t_{1/2}$ for Ba-137m starting with a reading other than the largest one recommended in the experiment.

(Corrected readings are used)

Selected cpm 160 Time (160) 300 s

Selected cpm/2 80 Time (80) 448 s (Estimate if necessary)

Time (160) - Time (80) = 148 s

$t_{1/2}$ Ba-137m 148 s

$t_{1/2}$ Ba-137m 2.5 min The cpm/2 value has only 2 significant figures.