

Radioactive decay and nuclear binding energy

Physics grades 11-12 (A Level · IB · Class 11-12) · Lab

Name: _____ Date: _____ Class: _____

Radioactive decay is random, yet a large sample decays in a smooth, exponential way. In this lab you model the decay of 120 nuclei with dice, plot the results and use them to find the half-life of the model, then compare it with the value predicted from the chance of decay.

Level: Physics grades 11-12 (A Level · IB · Class 11-12) · **Curriculum:** IB E.3-E.5

Aim

To model radioactive decay with dice, to find the half-life of the model from a graph and from the gradient of $\ln N$ against the number of throws, and to compare it with the value predicted from the chance of decay.

Equipment

- 120 identical dice (or 120 small cubes with one face marked)
- a large tray or shoebox lid with a rim
- a second container for removed dice
- graph paper or a spreadsheet
- calculator with a $\ln$ key

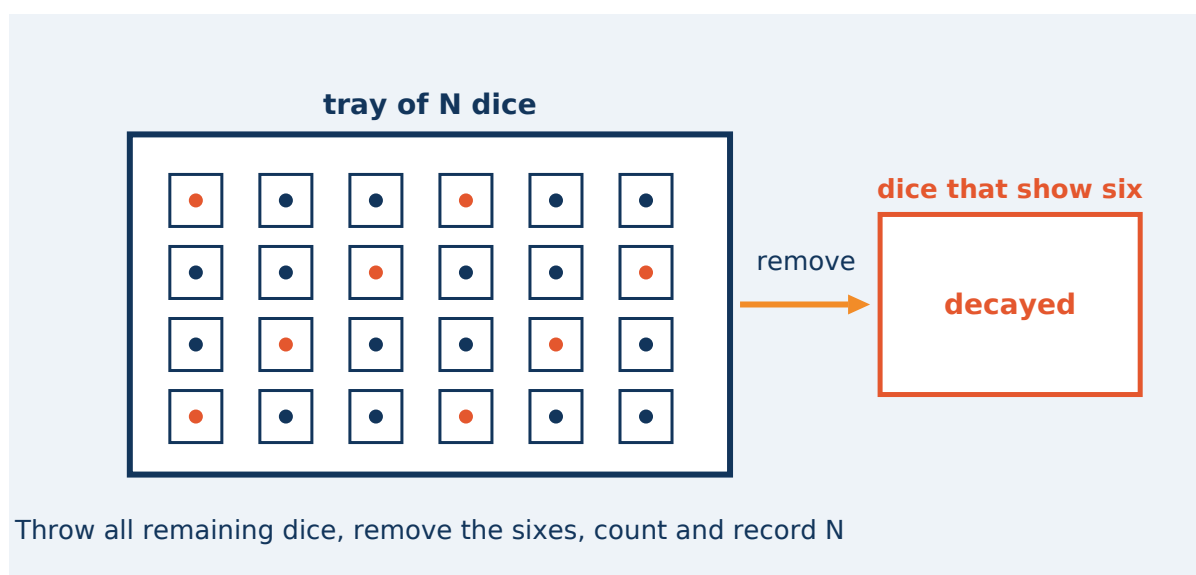
Safety

Safety

This is a model: no radioactive source is used. Throw the dice gently inside the tray so that none fall on the floor, where they are a slipping hazard, and pick up any stray dice at once.

Method

1. Put all 120 dice in the tray and record $N = 120$ for throw 0.
2. Shake the tray so that all the dice are thrown, and remove every die showing a six: these represent nuclei that have decayed.
3. Count the dice that remain in the tray and record N for throw 1.
4. Throw only the remaining dice and repeat the removal until you have done 10 throws, or until fewer than 10 dice are left.
5. Plot N against the number of throws n , and also calculate $\ln N$ for each throw.



Set-up: a throw, the removal of the sixes and the count.

Results

Sample results from one run:

Throw n	0	1	2	3	4	5	6	7	8	9	10
Dice left N	120	102	90	74	61	48	39	35	33	27	22

Analysis questions

Question 1 Why results vary

Explain why a second run with the same number of dice would give different counts, and why this is realistic for radioactive decay.

Question 2 Expected values

Each die has a $1/6$ chance of being removed in each throw. Calculate the expected number left after 10 throws and compare it with the sample result of 22.

Question 3 Half-life from the graph

Plot N against n for the sample data and use the graph to find the number of throws taken for N to fall from 120 to 60.

Question 4 Straight-line plot

Calculate $\ln N$ for each throw, plot $\ln N$ against n and find the gradient of the best-fit line. State what the gradient represents.

Question 5 Half-life from the gradient

Use the decay constant found in the previous question ($\lambda = 0.17$ per throw) to calculate the half-life in throws.

Question 6 Prediction from probability

The chance that a die decays in one throw is $1/6$. The fraction left after each throw is $5/6$. Show that the model has $\lambda = \ln(6/5)$ per throw, calculate the predicted half-life, and compare it with your result.

Question 7 Improving the reliability

State why the last few readings are the least reliable, estimate the percentage fluctuation for $N = 22$, and suggest one improvement.