**Half-life of clay dice**

To model the random nature of half-life, dice made out of modelling clay are thrown in the air. Those that land showing a dot on the top face decay (and are rolled into balls) the others do not. The total number of clay dice remaining after each throw measures the amount of the radioactive element that has not decayed. This is proportional to the level of radiation emitted by the source.

**N.B.** Rolling the dice into balls shows that the radioactive atoms have changed into other types of atoms and have not disappeared (which is a common misunderstanding). When thrown, the balls never land with a dot on a top face.

Repeating the same experiment with dice that have fewer or greater sides with dots, or different shaped dice, gives a different decay rate that is specific to the ‘radioactive isotope’ used.

**Apparatus and materials**

* Plasticine or similar modelling clay – enough for each student to make ten dice.

**Procedure**

* Each student makes ten dice out of modelling clay (e.g. Plasticine) and on two faces they make a small dot with the end of a pencil.

If you want to include background radiation in the count, then have about 20 similar dice of your own.

* Record the total number of dice (after zero throws) on the board.
* The students all toss their dice and then roll into a ball each one that lands with a dot on its top face.

Toss your dice as well but do not roll any into a ball.

* Count up all the dice that are remaining. The easiest way is to have a show of hands for those with 10 left, 9, 8, and so on. A quick mental calculation on the board will impress the calculator generation! Overtly add on the number of your own dice that did not land with a dot on the top face.

Record the total number remaining each time.

* Repeat the procedure about 10 times or until the number of dice run very low.

At some stage a student usually notices that the number of dice you are declaring that you have left is going up as well as down. Challenge them as to why they think this is happening and someone should realise that you are modelling the random background radiation. If you record your values as you go then you can use them to calculate the average background count to subtract from the total count each time.

You may realise that the background count cannot really be represented by the number of undecayed dice, as it is largely made up of ionising radiation that does not originate in the room. Only the brightest students will notice this and these will usually understand the simplification that has been made to illustrate the learning ideas.

* Students should plot the results and use them to calculate the half-life of the dice (about 3 throws) in the usual way.

Students could also be given results that were obtained from dice that had different numbers of faces with dots on, and/or dice with different numbers of faces.

*Physics > Big idea PMA: Matter > Topic PMA5: Nuclear physics > Key concept PMA5.4: Radioactive half-life*

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| --- |
| **Response activity** |
| **Half-life of clay dice** |

**Overview**

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| --- | --- |
| Learning focus: | Radioactive half-life is the predicted time it takes for half of a large sample of radioactive nuclei to decay randomly. |
| Observable learning outcome: | Describe the decay of a radioactive material. |
| Activity type: | Clarifying - modelling |
| Key words: | Half-life, half-life graph, radioactive atom, radioactive isotope |

This activity can help develop students’ understanding by addressing the sticking-points revealed by the following diagnostic questions:

* Diagnostic question: Radioactive material
* Diagnostic question: Radioactive half-life
* Diagnostic question: Radioactive half-life graph

**What does the research say?**

Misunderstandings that may stem from a thinking that ‘only clearly determined events can lead to predictable outcomes’ are:

* a radioactive material will be safe and no longer radioactive after one half-life (Lijnse et al., 1990);
* *all* the radioactive atoms will have decayed after one half-life (or after *two* half-lives); and
* half-life is a special time before which, or at which, a particular nucleus decays (Hull and Hopf, 2020).

In each of these examples, students appear to have used the idea that ‘half-life’ is predictable, to develop a misunderstanding that the decay of particular radioactive atoms is also predictable. The last example additionally shows how some students (about a third of a sample of 55 students age 13-14) ascribe the predictive nature of a whole sample to a single radioactive nucleus (Hull and Hopf, 2020). In fact, an individual radioactive nucleus does not have a half-life and its decay is random. Half-life is instead, a *good predictor* of the time it takes for half of a sample of *very many* radioactive nuclei to decay.

Another misunderstanding students have is that atoms disappear during radioactive decay (Prather, 2005). Prather (2005) found that the majority (59%) of (n=258) undergraduate students believed that the mass or volume of a radioactive substance would reduce by half during one half-life. Expressed differently, this means that a radioactive object disappears as it decays. This misunderstanding is likely to stem from the fact that is not clear to a lot of students that radioactive materials contain both stable and unstable atoms.

**Ways to use this activity**

***There are no PowerPoint slides for this activity.***

This demonstration gives you the opportunity to re-teach a challenging concept, and show your students how it builds up from simpler ideas, using a structured teacher-led discussion.

You should use carefully selected questions to check your students’ understanding of each step, before progressing onto the next one.

The steps you follow in this demonstration are described on the teacher guidance sheet, and the following points provide guidance on what aspects of students’ understanding or misunderstanding to be aware of.

* The clay dice are rolled into balls rather than discarded, in order to illustrate that radioactive atoms do not disappear, they change into different types of (often stable) atoms.
* The throw of each di is random.
* All the dice that remain at the end of ten throws have landed without a dot on the top face ten times in a row. This is not a sequence that people expect from a series of random events.
* A di is equally likely to land with a dot on top on the tenth throw as it was on the first throw. There is no difference between each throw that is affected by previous sequences of throws.

**Equipment**

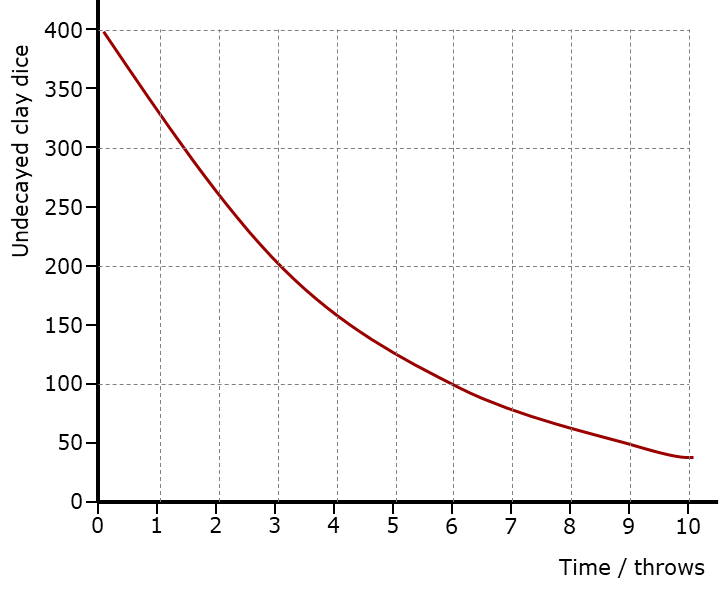
For each student:

Modelling clay such as Plasticine, sufficient to make ten dice.

**Health and safety**

Practical work should be carried out in accordance with local health and safety requirements, guidance from manufacturers and suppliers, and guidance available from CLEAPSS.

**Expected answer**

A graph similar to this one:

**Acknowledgments**

Developed by Peter Fairhurst (UYSEG).

Image: Peter Fairhurst (UYSEG).

**References**

Hull, M. M. and Hopf, M. (2020). Student Understanding of Emergent Aspects of Radioactivity. *International Journal of Physics and Chemistry Education,* 12(2).

Lijnse, P. L., et al. (1990). Pupils' and mass-media ideas about radioactivity. *International Journal of Science Education,* 12.1.

Prather, E. (2005). Students' beliefs about the role of atoms in radioactive decay and half-life. *Journal of Geoscience Education,* 53(4)**,** 345-354.