**Carbon dating**

Most of the carbon in the air is carbon-12.

One in every trillion carbon atoms in air is carbon-14.

This is the same proportion of carbon-14 that is in all living things.

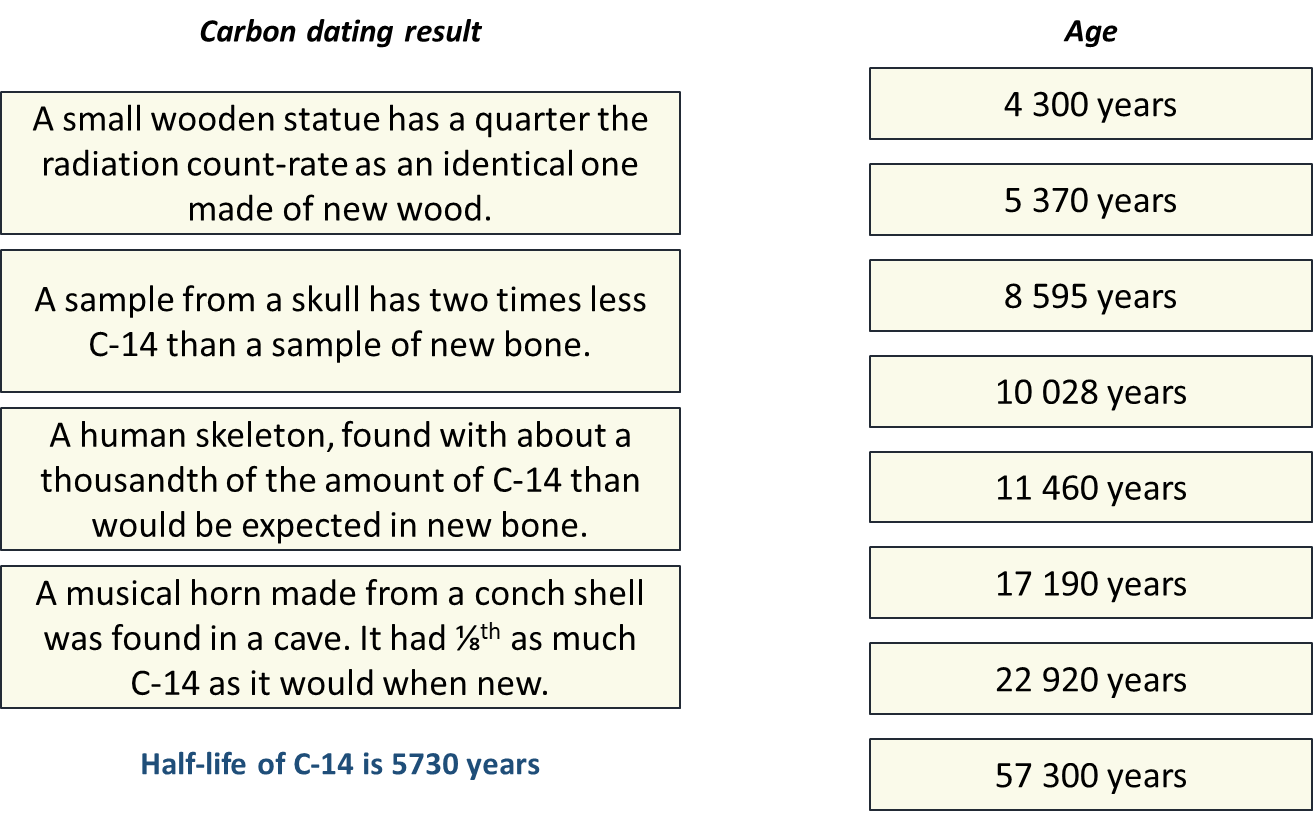


In **dead things**, the proportion of carbon-14 slowly goes down.

Carbon-14 is radioactive. It has a half-life of 5730 years.

For each carbon dating result, pick the best age from the list.

*Rule lines between columns to show what you think.*



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

|  |
| --- |
| **Diagnostic question** |
| **Carbon dating** |

**Overview**

|  |  |
| --- | --- |
| 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: | Make calculations using values of half-life. |
| Question type: | Linking ideas |
| Key words: | Half-life, radioactive atom, radioactive isotope |

**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.

**Ways to use this question**

This task is intended for discussion in pairs or small groups. It is best done as a pencil and paper exercise.

Students should read the statements and follow the instructions on the worksheet. Listening in to the conversations of each group will often give you insights into how your students are thinking. Each member of a group should be able to report back to the class.

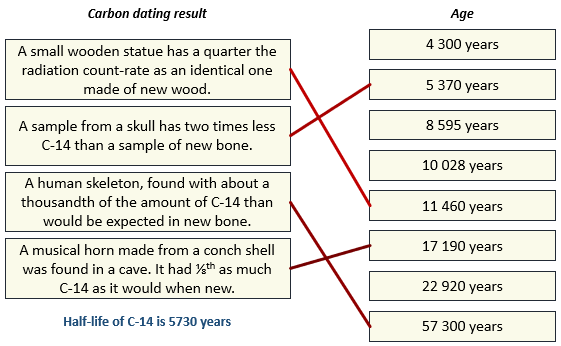
Feedback from each group can be used, with careful teacher questioning, to bring out a clear description or explanation of the science.

*Differentiation*

The quality of the discussions can be improved with a careful selection of groups; or by allocating specific roles to students in each group. For example, you may choose to select a student with strong prior knowledge as the scribe, and forbid them from contributing any of their own answers. They may question the others and only write down what they have been told. This strategy encourages contributions from more members of each group.

NB in any class, small group discussions typically improve over time and a persistence with this strategy is often very successful in the medium to long term.

**Expected answers**



**How to respond - what next?**

The oldest known wooden art is the Shigar Idol. It is 12 500 years old, which is about two half-lives of C-14.

Some students may choose 8 595 years, which one half-life and then half as much time again. These students are using the common misunderstanding that there will be no radioactive material remaining after two half-lives.

Some students may think there will be no radioactive material left after one half-life, and are likely to choose 4 300 years, which is ¾ of one half-life.

The skull is one half-life old, which is 5730 (±40) years.

For the human skeleton, it takes ten half-lives (57 300 years) for there to be (½)10 = 1/1024 of the carbon-14 atoms remaining that have not decayed into nitrogen atoms.

Students that have the misunderstanding that all the carbon-14 atoms decay after two half-lives are most likely to select either 10 028 or 11 460 years.

A musical horn made from a conch shell was found in a cave in the Pyrenees and was found to be

17 000 years old, which is approximately three half-lives (½ x ½ x ½ = ⅛).

Some students may think that because ⅛ is four times smaller than ½, it takes four half-lives to reduce the amount of C-14 to ⅛ of its original amount (22 920 years)

If students have misunderstandings about making calculations using values of half-life, it can help to model what happens to a radioactive material as it decays. Practice calculations can then be used to consolidate understanding.

The following BEST ‘response activity’ could be used in follow-up to this diagnostic question:

* Response activity: Half-life of pizza

**Acknowledgments**

Developed by Peter Fairhurst (UYSEG).

Image by blende12 from Pixabay.

**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.