Unit 15 · Earth and the Universe

HARDER PRACTICE QUESTIONS

Full marks 43

Write your answers on separate paper. Show your working. Half-lives: carbon-14 5,730 years, potassium-40 1,250 million years, uranium-238 4,470 million years. The Earth is about 4,540 million years old.

1 Spot the error [3]

Shristi wrote: “Half of a sample’s carbon-14 decays in 5,730 years, so the other half decays in the next 5,730 years. After 11,460 years nothing is left.”
What is wrong? How much is really left after 11,460 years, and after 51,570 years?

2 Between two half-lives [4]

A laboratory finds that a piece of charcoal has 35% of the carbon-14 of living wood.

i. Between which two whole numbers of half-lives does its age lie? So between which two ages?
ii. Estimate its age by assuming the share falls in a straight line between those two points. Will the real age be more or less than this, and why?
iii. Charcoal from the first shrine at Lumbini is about 2,600 years old. Is its share of carbon-14 more or less than 50%?

3 Two layers of ash [4]

In a cliff, from the bottom up: sandstone A, an ash bed dated to 7.2 million years, sandstone B with a three-toed horse’s tooth, an ash bed dated to 6.8 million years, then mudstone C. A crack filled with dark igneous rock cuts through all of them.

i. How old is the tooth? Give your reasoning.
ii. What can you say about the age of the igneous rock?
iii. A tooth of the same kind of horse is found in an undated layer 300 km away. What does it suggest, and what makes this reasoning work?

4 The rock’s clock [4]

A volcanic rock had no argon-40 when it formed. Now, for every atom of potassium-40 left, there are 7 atoms of argon-40 made from it.

i. What fraction of the potassium-40 is left? How old is the rock?
ii. Another rock has 3 atoms of argon-40 for each potassium-40. How old is it?
iii. Someone reports a grain with 3 atoms of lead-206 for each uranium-238 atom. Why must the report be wrong?

5 Show that [3]

i. Show that after a time t the fraction of a radioactive parent left is $\left(\frac{1}{2}\right)^{t/T}$, where T is the half-life.

ii. Show that the fraction of daughter atoms made is $1 - \left(\frac{1}{2}\right)^{t/T}$, and so that the daughter equals the parent after exactly one half-life.

6 The Earth in a day [4]

Squeeze the Earth’s 4,540 million years into one day of 24 hours.

i. The dinosaurs died out 66 million years ago. How many minutes before midnight is that?
ii. The Quaternary, with the ice ages and humans, began 2.6 million years ago. How many seconds before midnight?
iii. Carbon dating reaches back 50,000 years. How much of the day is that?

7 Read the counts [4]

A laboratory counts beta particles from 1 g of carbon from each sample. Living wood gives 14 counts a minute.

Sample	A: rice straw from a mud wall	B: bone from a cave	C: charcoal from a hearth	D: Siwalik crocodile tooth
Counts a minute	13	3.5	1.75	0

i. Find the ages of B and C.
ii. Is A older or younger than one half-life? Roughly how old?
iii. What does D's count mean, and what is wrong with dating it this way?

8 Into orbit [3]

NepaliSat-1 went round the Earth once every 92 minutes, at about 7.7 km/s.

i. How far did it travel in one orbit?
ii. How many orbits a day?
iii. Voyager 1 is about 25 billion km away. Taking light's speed as 300,000 km/s, how long does its signal take to reach us?

9 Put them in order [3]

Write these in the order they happened: Apollo 11 lands on the Moon; Hubble is launched; Gagarin flies round the Earth; Sputnik 1; the first crew on the ISS; Viking 1 lands on Mars; NepaliSat-1; Salyut 1.

10 Fair test [3]

In a box planetarium, Rojina thinks that bigger holes make brighter stars on the ceiling. Plan a fair test.

i. What will she change, and what will she observe?
ii. Name two things she must keep the same.
iii. What result would support her idea?

11 Correct the misconceptions [3]

The paragraph has three mistakes. Write each one and correct it.

Nabin wrote: "Shaligrams can be carbon-dated, since their shells contain carbon. The Siwalik fossils show that Ramapithecus, found in the Tinau Khola, was an early human. Dinosaur bones are common in Nepal's Tethys rocks."

12 Think [3]

Suppose carbon-14's half-life were ten times longer, 57,300 years. How far back could carbon dating reach? Would it be better or worse for dating a house built 100 years ago? Explain.

13 Make your own [2]

Invent a carbon-dating problem whose answer is a whole number of half-lives. Give the counts a minute of living carbon and of your sample, and work out the age.