Reading 75

Two Atomic Clocks

The nucleus of a radioactive atom disintegrates spontaneously and forms an atom of a different element while emitting radiation in the process. The original atom is called the parent isotope* and its stable product is called the daughter or progeny isotope. For example, rubidium-87 decays by emitting an electron from its nucleus to form a stable daughter called strontium-87. Because the rate of nuclear decay is constant regardless of temperature and pressure conditions, radioactive decay provides a dependable way of keeping time. Radioactive isotopes **alter** from one type of atom to another at a fixed rate from the moment they are created anywhere in the universe. Since we can calculate the decay rate and also count the number of newly formed progeny atoms and the remaining parent atoms, we can use the ratio as a kind of clock to measure the age of minerals and other materials.

The rate at which a radioactive element decays is known as the half-life of the element. **This** is the time necessary for one-half of the original number of radioactive atoms in a sample to decay into a daughter product. After two half-lives, the number of atoms remaining after the first half-life will have decayed by half again. Thus, the number of remaining parent atoms is reduced geometrically over time. With some elements, the half-life is very long. Rubidium-87, for example, has a half-life that has been estimated at nearly 48.8 billion years, much longer than the current estimated age of the universe. With other elements, this period can be as short as a few days or even minutes. If we know the half-life of a decaying element, it is possible to calculate the ratio of parent to stable progeny that will remain after any given period of time.

Geologists use a sensitive instrument called a mass spectrometer to detect tiny quantities of the isotopes of the parent and progeny atoms. By measuring the ratio of these, they can calculate the age of the rock in which the rubidium originally crystallized. Because the number of progeny is growing as the parent is decaying and this is occurring at a constant rate, after one-half life the ratio is one parent to one progeny. After two half-lives the ratio is 1 to 3.

Rubidium-87 has often been used to date rocks since it is a widespread element. Various elements including rubidium are incorporated into minerals as they crystallize from

magma* or metamorphic rock. During this process the rubidium is separated from any strontium progeny that existed before the rock formed and so we know that the measurable alteration from parent to progeny can be dated from this point. As the radioactive decay of rubidium-87 begins, new progeny atoms of strontium-87 start to accumulate in the rock. In the dating of rocks using these elements, it is important that the rock sample has not been altered subsequent to its formation by other geologic processes or contamination of any kind. Rocks as old as 4.6 billion years can be dated with some degree of reliability using this method.

Another radioactive element useful for dating is carbon-14, which decays into nitrogen-14. [A] With a half-life of 5,730 years, carbon-14 decays much more rapidly than rubidium-87 and so is useful for measuring the ages of objects from the recent historical and geologic past, such as fossils, bones, wood, and other organic materials. Whereas rubidium-87 is incorporated into rocks during their formation, carbon-14, which is an **essential** element of the cells of organisms, becomes incorporated into living tissues as organisms grow. [B] The ratio of carbon-14 to stable carbon isotopes in the organism is the same as it is in the atmosphere. [C] When a living organism dies, no more carbon dioxide is absorbed and so no new carbon isotopes are added. [D] The daughter nitrogen-14 isotope, existing in gaseous form, leaks out of the dead organism, and thus, we cannot use it to compare the ratio of original to daughter as is done with rubidium-87 and its daughter. However, as the amount of carbon-14 in the dead organism becomes less over time, we can compare the proportion of this isotope remaining with the proportion that is in the atmosphere and from this calculate the approximate number of years since the organism has died. Dating dead organic material by this method is moderately reliable in samples up to about 50,000 years old, but beyond that the accuracy becomes unreliable.

‘isotope: one of the differing forms of an atomic element
‘magma: material that is in liquid form and which cools on the Earth’s surface to form rock

1 The word "alter" in the passage is closest in meaning to
A adapt
B change
C revise
D vary

2 The rate of nuclear decay in rubidium-87
A is always the same
B changes over time
C depends on temperature
D depends on temperature and pressure

3. The word "This" ("This is the time necessary…") in the passage refers to
A element
B half-life
C rate
D time

4 The half-life of an element
A is a reliable way of measuring sample size
B is a measure of decay rate in radioactive elements
C is considered an unreliable way of calculating age
D approximately half the age of the atoms it contains

5 What can be inferred about the reliability of using radioactive atoms to calculate ages of rock samples?
A The reliability increases over time.
B The reliability decreases with older samples.
C The reliability of the parent atom is greater than the progeny.
D The reliability of the progeny atom is greater than the parent.

6 According to the passage, from what point can we measure the ages of rocks?
A From the point at which rubidium-87 became part of the rock structure
B From the point at which strontium-87 started to decay
C From the point at which the rocks rubidium-87 and strontium-87 joined
D From the point at which later contamination entered the rock samples

7 The word "essential" in the passage is closest in meaning to
A redundant
B stable
C dependable
D vital

8 According to paragraph 5, what happens to an organism after it dies?
A It tends to deteriorate rapidly.
B The various carbon isotopes decay.
C The supply of carbon-14 is no longer replenished.
D The stable carbon isotopes deteriorate.

9 According to paragraph 5, why can’t scientists compare the ratio of carbon-14 to nitrogen-14?
A The amount of nitrogen-14 is not predictable.
B The ratio of these two elements doesn't change.

C Nitrogen-14 has an unpredictable decay rate.
D Carbon-14 tends to evaporate too quickly.

10 According to paragraph 5, the amount of carbon-14 in an organism
A replaces other carbon isotopes after an organism dies
B tends to be the same as the other carbon isotopes
C increases rapidly when an organism dies
D deteriorates from the moment of death

11 Look at the four squares [ ] that indicate where the following sentence could be added to the passage.
Both the unstable carbon-14 and stable carbon isotopes are taken in from the carbon dioxide present in the atmosphere.
Where would the sentence best fit?
Choose the letter of the square that shows where the sentence should be added.

12 Select the appropriate phrases from the answer choices and match the dating technique to which they relate. TWO of the answer choices will NOT be used.
Write the letters of the answer choices in the spaces where they belong.

ANSWER CHOICES

A Can be used for dating artifacts made of bones or wood
B Destroys progeny isotopes
C Essential to living organisms
D Has a half-life of billions of years
E Incorporated into minerals when they crystallized
F Progeny cannot be used for dating
G Unreliable for dating samples
H Used for dating dead trees
I Used for dating rocks

Rubidium-87
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Carbon-14
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Источник задания: Cambridge Preparation to the TOEFL

Reading 75 — Keys

1 B
When something "alters," it "changes" or takes a different form.
2 A
The passage states that the rate of decay is constant, regardless of conditions.
3 B
The element's half-life is the time necessary for one-half of the original number of radioactive atoms in a sample to decay.
4 B
The rate at which a radioactive element decays, its half-life, is used as a way to calculate its age.
5 B
According to the passage, "Rocks as old as 4.6 billion years can be dated with some degree of reliability." This implies that dating rocks that are older than this is probably less reliable.
6 A
The phrase "from this point" refers to the separation of rubidium and strontium that occurs when the minerals crystallize from magma or metamorphic rock. That point is when the elements are incorporated into the minerals.
7 D
When something is "essential," it is "vital" or necessary.
8 C
According to the passage, when an organism dies, "no more carbon dioxide is absorbed."
9 A
According to the passage, the nitrogen-14 isotope leaks out so it cannot be used for comparisons.
10 D
The passage states that the amount of carbon-14 in the dead organism becomes less over time.
11 C
The information about the kinds of isotopes taken in from the atmosphere would follow the fact that the isotopes are in the same amount in the atmosphere as in the organism. It would precede the information about what happens after an organism dies.

12
Rubidium-87 — D E I
Rubidium-87 has a half-life of nearly 48.8 billion years.

Rubidium-87 is incorporated into minerals as they crystallize from magma or metamorphic rock.

Rubidium-87 is formed when the rock is formed.

Carbon-14 — A C F H

Bones or wood are organic materials.

Carbon-14 is an essential element of the cells being incorporated into living tissue.

Carbon-14 has the progeny nitrogen-14, which is a gas that leaks out of the organism and, therefore, is not useful for dating.

Trees are organic.