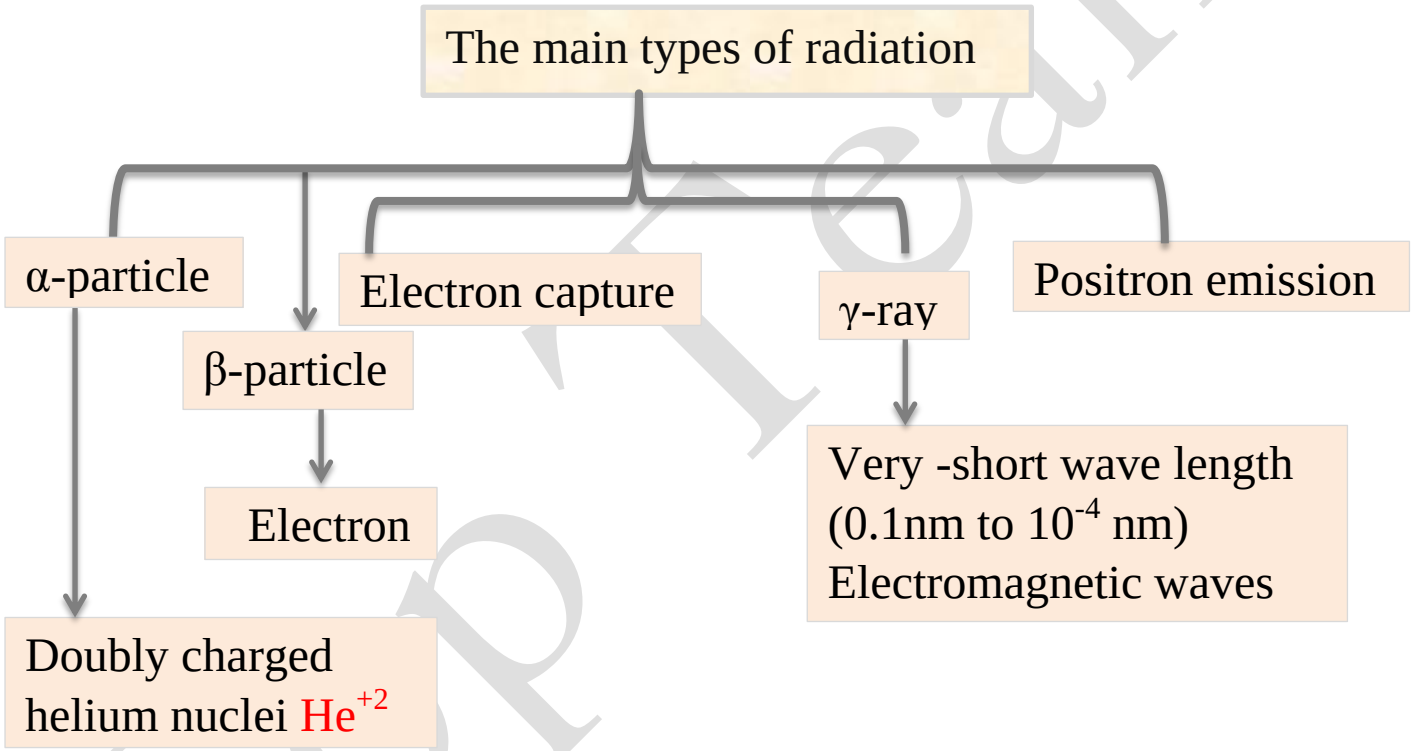
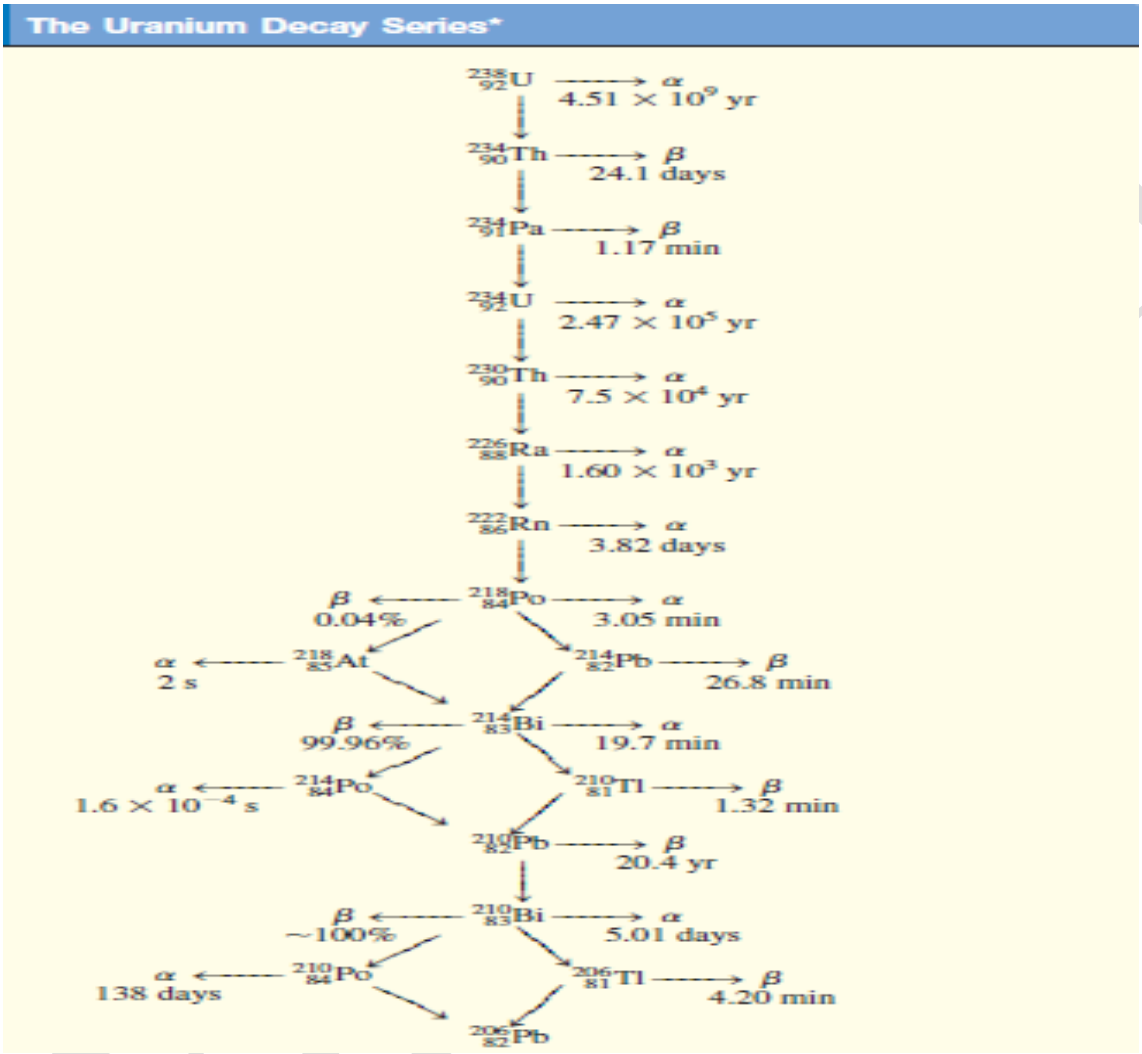
Natural radio activity

Radio activity: → the spontaneous emission by unstable nuclei of particles or electromagnetic radiation or both.



Radioactive decay series: → is a sequence of nuclear reactions that ultimately result in the formation of a stable isotope.



- Uranium 238 decay in 14 steps.

- The first step:→ The decay of uranium 238 to thorium 234

$$^{238}_{92}U \rightarrow {}^{234}_{90}Th + {}^{4}_{2}\propto$$

- The next step:→ $^{234}_{90}Th \rightarrow {}^{234}_{91}Pa + {}^{0}_{-1}\beta$

Parent: → the beginning radioactive isotope.

Daughter:→ the product of radioactive decay.

Kinetics of radioactive decay

- All radioactive decay obey first order Kinetics.

Rate of decay at time t = λ N

λ → first order rate constant.

N → number of radioactive nuclei present at time t.

The number of radioactive nuclei # at time zero (N_0)

And at time t (N_t)

$$\ln \frac{Nt}{No} = -\lambda t$$

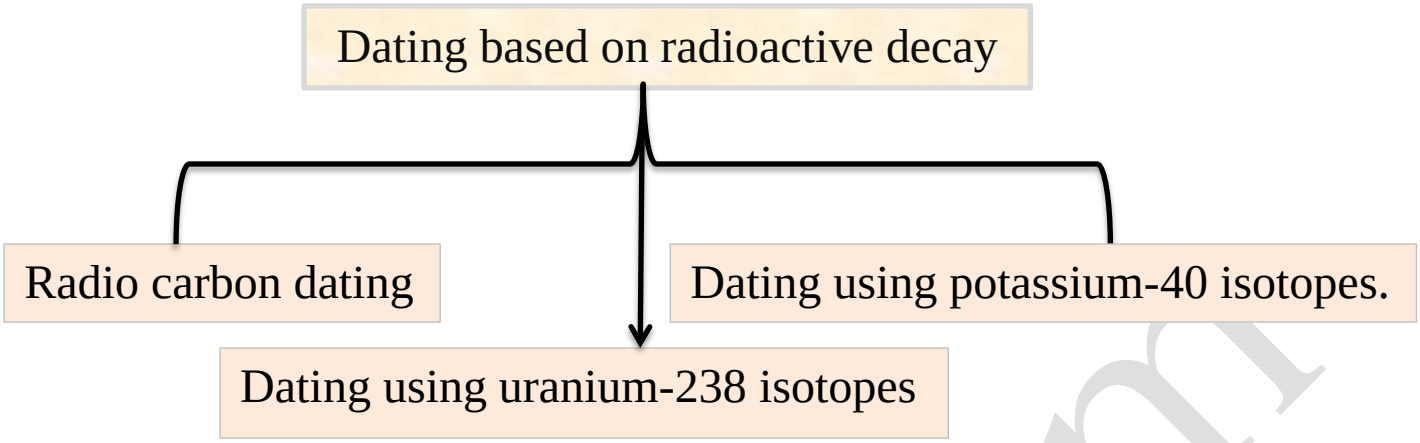
The half life time of the reaction

$$\frac{Nt}{No} = e^{-\lambda t}$$

$$T_{1/2} = \frac{0.693}{\lambda}$$

Note that

- ☒ Half-Lives of radioactive isotope vary greatly from nucleus to nucleus.
- ☒ Rate constants of radioactive isotopes vary greatly from nucleus to nucleus.
- ☒ Rate constants are unaffected by changes in environmental conditions such as temperature and pressure.



❖ The half-lives of radioactive isotopes have been used as "atomic clocks" to determine the ages of certain objects.

1) Radio carbon dating

The carbon-14 isotope is produced from nitrogen when bombarded by cosmic rays.

$$^{14}_{7}N + ^{1}_{0}n \rightarrow ^{14}_{6}C + ^{1}_{1}H$$

The radioactive carbon-14 decay according to the equation.

$$^{14}_{6}C \rightarrow ^{14}_{7}N + ^{0}_{-1}\beta$$

2) Dating using uranium 238 isotopes.

Some of intermediate products in the uranium decay series have very long half-lives.

This series is particularly suitable for estimating the age of rocks in the earth and of extraterrestrial objects.

The half-life for the first step ($^{238}_{92}U$ to $^{234}_{90}Th$) is $4.51 * 10^9$yr.

This is about 20.000 times the second largest value which is the half-life for ($^{238}_{92}U$ to $^{230}_{90}Th$) .

The half-life for the overall process.

$$^{238}_{92}U \rightarrow {}^{206}_{82}Pb + 8\ {}^{4}_{2}\alpha + 6\ {}^{0}_{-1}\beta \qquad t_{1/2} = 4.5*10^6 yr$$

In naturally occurring uranium minerals we should and do find some lead-206 isotopes formed by radioactive decay. Assuming that no lead was present when the mineral was formed and that the mineral has not undergone chemical changes that would allow the lead-206 isotope to be separated from the parent uranium-238, it is possible to estimate the age of the rocks from the mass ratio of $^{206}_{82}Pb$ to $^{238}_{92}U$. The Previous equation tells us that for every mole, or 238 g, of uranium that undergoes complete decay, 1 mole, or 206 g, of lead is formed. If only half a mole of uranium-238 has undergone decay, the mass ratio $^{206}_{82}Pb$ /$^{238}_{92}U$. Becomes

$$\frac{206\ g/2}{238\ g/2} = 0.866$$

and the process would have taken a half-life of $4.51*10^9$ yr to complete .Ratios lower than 0.866 mean that the rocks are less than $4.51*10^9$ yr old, and higher ratios suggest a greater age. Interestingly, studies based on the uranium series as well as other decay series put the age of the oldest rocks and, therefore, probably the age of Earth itself at $4.5*10^9$, or 4.5 billion, years.

3) Dating using potassium 40-isotopes.

The radioactive potassium 40-isotopte decay by several different modes.

The relevant one as far as dating is concerned is that of electron capture.

$^{40}_{19}\mathrm{K} + {}^{0}_{-1}e \rightarrow {}^{40}_{18}\mathrm{Ar}$ $\quad t_{1/2} = 1.2*10^{9}\mathrm{yr}$

The accumulation of gaseous argon-40 is used to gauge the age of a specimen.

When a potassium-40 atom in mineral decay, argon 40 is trapped in the lattice of the mineral and can escape only if the material is melted.

Knowing the ratio of argon-40 to potassium-40 in the mineral and the half-life of decay makes it possible to establish the ages of rock ranging from millions to billions of years old.

Choose

1) The Spontaneous emission by unstable nuclei of particles or electromagnetic radiation or both is ……..

A) radioactivity
C) decay
B) Half-life time
D) None of them

2) ….. is a doubly charged helium nuclei He^{+2}.

A) α-particle
C) γ-particle
B) β-particle
D) electron capture

3) γ-ray has very short wave length ranging from ……..to…….

A) 1nm-10^{3}nm
C) 0.1nm-10^{-4}nm
B) 2nm-10^{-4}nm
D) 0.1nm-10^{3}nm

4) ……is a sequence of nuclear reactions that ultimately result in the formation of a stable isotope.

A) radioactivity
C) Half-life time
B) Radioactivity decay series
D) None of them

5) Uranium 238 decay in ……..steps.

A) 5 step
C) 14 step
B) 22 step
D) 7 step

6) The beginning radioactive isotope is called…….

A) parent
C) mother
B) brother
D) daughter

7) The product of radioactive decay is called…….

A) parent
C) mother
B) brother
D) daughter

8) All radioactive decay obey……. Kinetics.

A) First order
C) Third order
B) second order
D) None of them

9) The half-life time of the reaction is equal…….

A) $T_{1/2} = \frac{\lambda}{0.693}$
C) $T_{1/2} = \frac{0.693}{\lambda}$
B) $T_{1/2} = \lambda * 0.693$
D) $T_{1/2} = \frac{x}{v}$

10) What fraction of radioactive atoms remains in a sample after six half-lives?

A) zero
C) 1/16
B) 1/6
D) 1/64

11) Carbon-11 is a radioactive isotope of carbon. Its half-life is 20.3 minutes. What fraction of the initial number of carbon-11 atoms in a sample will remain after 81 minutes?

A) _ C) 1/2

B) 1/4 D) 1/32

Solution

$T_{1/2}$ = 20.3min

$\lambda = \frac{0.693}{20.3} = 0.034$

$\frac{Nt}{No} = e^{-\lambda t}$

$\frac{Nt}{No} = e^{-0.034*81} = \frac{1}{16}$

12) Cobalt-60 is a beta emitter with a half-life of 5.3 years. Approximately what fraction of cobalt-60 atoms will remain in a particular sample after 26.5 years?

A) 1/5 C) 1/26

B) 1/16 D) 1/32

Solution

$T_{1/2}$ = 5.3min

$\lambda = \frac{0.693}{5.3} = 0.130$

$\frac{Nt}{No} = e^{-\lambda t}$

$\frac{Nt}{No} = e^{-0.130*26.5} = \frac{1}{32}$

13 Cobalt-60 is a beta emitter with a half-life of 5.3 years. Approximately what fraction of the cobalt-60 atoms in a particular sample will remain after 32 years?

A) 1/6
C) 1/16
B) 1/8
D) 1/64

Solution

$T_{1/2}$ = 5.3min

$\lambda = \frac{0.693}{5.3} = 0.130$

$\frac{Nt}{No} = e^{-\lambda t}$

$\frac{Nt}{No} = e^{-0.130*32} = \frac{1}{64}$

14) If 12% of a certain radioisotope decays in 5.2 years, what is the half-life of this isotope?

A) 0.59 yr
C) 22 yr
B) 1.7 yr
D) 28 yr

Solution

Let N_o = 100

N_t = 100-12 =88

$ln\frac{Nt}{No} = -\lambda t$

$ln\frac{88}{100} = -\lambda 5.2$

$\lambda = 0.024$

$T_{1/2} = \frac{0.693}{0.024} = 28\ yr$

15) Polonium-208 is an alpha emitter with a half-life of 2.90 years. How many milligrams of polonium from an original sample of 2.00 mg will remain after 8.00 years?

A) 0.147 mg
C) 0.725 mg
B) 0.296 mg
D) 6.77 mg

Solution

$T_{1/2} = 2.9\ yr$

$$\lambda = \frac{0.693}{2.9} = 0.238$$

$$\frac{Nt}{No} = e^{-\lambda t}$$

$$\frac{Nt}{2} = e^{-0.238*8}$$

$N_t = 2*e^{-0.238*8} = 0.29mg$

16) The half-life of ^{90}Sr is 29 years. What fraction of the atoms in a sample of ^{90}Sr would remain 175 years later?

A) 0.17
C) 0.062
B) 0.12
D) 0.015

Solution

$T_{1/2} = 29\ yr$

$$\lambda = \frac{0.693}{29} = 0.0238$$

$$\frac{Nt}{No} = e^{-0.0238*175} = 0.015$$

17) The heaviest known isotope of hydrogen is called tritium ,$^{3}_{1}H$. It decays by beta emission, and has a half-life of 12.3 years. What fraction of a tritium sample will remain after 5.20 years ?

A) 0.0210
C) 3.41
B) 0.746
D) 0.254

Solution

$T_{1/2} = 12.3\ yr$

$$\lambda = \frac{0.693}{12.3} = 0.056$$

$$\frac{Nt}{No} = e^{-\lambda t} = e^{-0.056*5.2} = 0.74$$

18) A rock contains 0.37 mg of Pb-206 and 0.95 mg of U-238. Approximately how many U-238 atoms were in the rock when it was formed billions of years ago? (The half-life for $^{238}U \rightarrow {}^{206}Pb$ is 4.5×10^{9} yr.)

A) 1.32 atoms
C) 2.4×10^{18} atoms
B) 5.8×10^{-6} atoms
D) 3.5×10^{18} atoms

19) A rock contains 0.37 mg of Pb-206 and 0.95 mg of U-238. The half-life of the decay series U-238 → Pb-206 is 4.5×10^{9} yr. Assuming no Pb-206 was present in the rock initially, how old is the rock?

A) 1.7×10^{9} yr
C) 2.7×10^{6} yr
B) 5.2×10^{9} yr
D) 2.4×10^{9} yr

20) The ^{14}C activity of some ancient Peruvian corn was found to be 10 disintegrations per minute per gram of carbon. If present-day plant life shows 15 dpm/g, how old is the Peruvian corn? The half-life of ^{14}C is 5730 yr.

A) 1,455 yr
C) 3,350 yr
B) 1,910 yr
D) 3,820 yr

21) Charcoal found under a stone at Stonehenge, England, has a carbon-14 activity that is 0.60 that of new wood. How old is the charcoal? (The half-life of carbon-14 is 5,730 years.)

A) Less than 5,730 yr
C) Between 11,460 and 17,190 yr
B) Between 5,730 and 11,460 yr
D) More than 17,190 yr

22) Charcoal samples taken from holes dug at Stonehenge, England, have a carbon-14 specific activity of 9.50 dpm per gram carbon. Living wood has a specific activity of 15.3 dpm per gram of carbon. Given that the half-life of carbon-14 is 5730 yr, how long ago was the wood part of a living plant?

A) 3940 yr
C) 9230 yr
B) 3550 yr
D) 5700 yr

23) Estimate the age of a bottled wine that has a tritium, ^{3}H, content 60% that of freshly bottled wine. Tritium decays by beta decay and has a half-life of 12.3 yr.

$$^{3}_{1}H \longrightarrow {}^{3}_{2}He + {}^{0}_{-1}\beta$$

A) 0.029 yr
C) 9.1 yr
B) 7.4 yr
D) 16 yr

24) How old is a bottle of wine if the tritium (^{3}H) content is 25% that of a new wine? The half-life of tritium is 12.5 years.

A) 0.25 yr
C) 25 yr
B) 3.1 yr
D) 38 yr

25) What would the atom ratio of ^{206}Pb to ^{238}U be in a uranium mineral from a rock that is 1.0×10^{9} years old? $t_{1/2}(^{238}U) = 4.5 \times 10^{9}$ yr.

A) 0.14
C) 0.22
B) 0.16
D) 0.86

26) The radioisotope potassium-40 decays to argon-40 by positron emission with a half-life of 1.3×10^{9} yr. A sample of moon rock was found to contain 78 argon-40 atoms for every 22 potassium-40 atoms. The age of the rock is

A) 8.1×10^{-10} yr
C) 2.8×10^{9} yr
B) 2.4×10^{9} yr
D) 4.6×10^{9} yr

27) The Rb-87/Sr-87 method of dating rocks is often used by geologists: $^{87}_{37}Rb \longrightarrow {}^{87}_{38}Sr + {}^{0}_{-1}\beta$ $t_{1/2}= 6.0 \times 10^{10}$ yr

Estimate the age of a rock sample in which the present-day mole ratio of Rb-87 to Sr-87 is 36:1.

A) 2.4×10^{9} yr

B) 1.7×10^{9} yr

C) 3.1×10^{11} yr

D) 4.1×10^{-11} yr