1. Starting with a sample of pure ^{66}Cu, 7/8 of it decays into Zn in 15 minutes. The corresponding half-life (in minute) is:
A) 3.75 B) 5 C) 7 D) 10 E) 15

2. ^{210}Bi (an isotope of bismuth) has a half-life of 5.0 days. The time (in day) for three-quarters of a sample of ^{210}Bi to decay is:
A) 2.5 B) 3.75 C) 10 D) 15 E) 20

3. Radioactive ^{90}Sr has a half-life of 30 years. What percent of a sample of ^{90}Sr will remain after 60 years?
A) 0% B) 14% C) 25% D) 50% E) 75%

4. The half-life of a radioactive isotope is 6.5 h. If there are initially 48×10^{32} atoms of this isotope, the number of atoms of this isotope remaining after 26 h is:
A) 12×10^{32} B) 6×10^{32} C) 3×10^{32} D) 6×10^{4} E) 3×10^{2}

5. At the end of 14 min, 1/16 of a sample of radioactive polonium remains. The corresponding half-life (in minute) is:
A) (7/8) B) (8/7) C) (7/4) D) (7/2) E) (14/3)

6. The half-life of a radioactive isotope is 140 days. In how many days does the decay rate of a sample of this isotope decrease to one fourth its initial decay rate?
A) 35 B) 70 C) 105 D) 210 E) 280

7. ^{40}K decays to ^{40}Ar with a half-life of 1.25×10^{9} yr. Assume that rocks contain no ^{40}Ar when they form, and that the only way ^{40}Ar can be present is through the decay of ^{40}K. If the ratio of ^{40}K to ^{40}Ar in a particular rock is found to be 1:3, what is the age (in year) of the rock?
A) 1.25×10^{9} B) 2.50×10^{9} C) 3.75×10^{9} D) 5.00×10^{9}
E) cannot be determined without knowing how much ^{40}K was in the rock to begin with

8. An isotope of Tc having a half-life of 6.0 h is used in bone scans. If a certain amount of this Tc is injected into the body, how long (in hour) does it take for its initial decay rate to decrease BY 99%?
A) 0.060 B) 3.3 C) 33 D) 40 E) slightly more than a month

9. The ratio of the radius of a classical electron (2.8×10^{-15} m) to the radius of a ^{4}He nucleus is
A) 2.0 B) 0.68 C) 1.47 D) 0.92 E) 2.4

1. Starting with a sample of pure ^{66}Cu, 7/8 of it decays into Zn in 15 minutes. The corresponding half-life (in minute) is:

A) 3.75 B) 5 C) 7 D) 10 E) 15

$N(t) = \frac{1}{8} N_o$

$\frac{1}{8} N_o = N_o * (\frac{1}{2})^n$

$\therefore n = 3$

$n = \frac{t}{t_{1/2}}$ $\therefore t_{1/2} = \frac{15}{3} = 5$ min

2. ^{210}Bi (an isotope of bismuth) has a half-life of 5.0 days. The time (in day) for three-quarters of a sample of ^{210}Bi to decay is:

A) 2.5 B) 3.75 C) 10 D) 15 E) 20

$t_{1/2} = 5$ day

$\frac{3}{4}$ of a sample of ^{210}Bi to decay → $\frac{1}{4} N_o$ remaning

$\frac{1}{4} N_o = N_o * (\frac{1}{2})^n$

$\therefore n = 2$

$n = \frac{t}{t_{1/5}}$ $\therefore t = 10$ day

3. Radioactive ^{90}Sr has a half-life of 30 years. What percent of a sample of ^{90}Sr will remain after 60 years?

A) 0% B) 14% C) 25% D) 50% E) 75%

$t_{1/2} = 30$ years

$n = \frac{60}{30} = 2$

$N(t) = N_o * (\frac{1}{2})^2 = \frac{1}{4} N_o$ remaning is 25%

4. The half-life of a radioactive isotope is 6.5 h. If there are initially 48×10^{32} atoms of this isotope, the number of atoms of this isotope remaining after 26 h is:

A) 12×10^{32} B) 6×10^{32} C) 3×10^{32} D) 6×10^{4} E) 3×10^{2}

$t_{1/2} = 6.5h$ $N_o = 48 * 10^{32}$

$n = \frac{26}{6.5} = 4$ | $N(t) = 48 * 10^{32} * \frac{1}{16}$

$\therefore N(t) = 3 * 10^{32}$

5. At the end of 14 min, 1/16 of a sample of radioactive polonium remains. The corresponding half-life (in minute) is: A) (7/8) B) (8/7) C) (7/4) D) (7/2) E) (14/3)

$N(t) = \frac{1}{16} N_o$ after 14 min

$\frac{1}{16} N_o = N_o * (\frac{1}{2})^n$

$\therefore n = 4$

$n = \frac{t}{t_{1/2}} = \frac{14}{4} = \frac{7}{2}$ min

6. The half-life of a radioactive isotope is 140 days. In how many days does the decay rate of a sample of this isotope decrease to one fourth its initial decay rate?

A) 35 B) 70 C) 105 D) 210 E) 280

$t_{1/2} = 140$

$A(t) = \frac{1}{4} A_o$

$A(t) = A_o e^{-\lambda t}$

$\frac{1}{4} A_o = A_o e^{-\lambda t}$

$\lambda = \frac{\ln(2)}{t_{1/2}}$

$\lambda = 4.95 * 10^{-3}$ day

$\frac{1}{4} = e^{-4.95 \times 10^{-3} t}$

$\therefore t = 280$ day

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$\frac{1}{4} A_o = A_o (\frac{1}{2})^n$

$\therefore n = 2$

$n = \frac{t}{t_{1/2}}$

$\therefore t = 280$

100% k 40

7. ^{40}K decays to ^{40}Ar with a half-life of 1.25×10^9 yr. Assume that rocks contain no ^{40}Ar when they form, and that the only way ^{40}Ar can be present is through the decay of ^{40}K. If the ratio of ^{40}K to ^{40}Ar in a particular rock is found to be 1:3, what is the age (in year) of the rock?

^{40}K ^{40}Ar

$t_{1/2} = 1.25 * 10^9$ year

$N(t) = N_0 * (\frac{1}{2})^n$

$1 = 4 * (\frac{1}{2})^n$

$n = 2$

$n = \frac{t}{t_{1/2}}$

$t = 2.5 * 10^9$ year

8. An isotope of Tc having a half-life of 6.0 h is used in bone scans. If a certain amount of this Tc is injected into the body, how long (in hour) does it take for its initial decay rate to decrease BY 99%?

A) 0.060 B) 3.3 C) 33 D) 40 E) slightly more than a month

$t_{1/2} = 6$ h

$A(t) = 0.01 A_0$

$0.01 * A_0 = A_0 (\frac{1}{2})^n$

$n = 6.6$

$t = 6.6 * 6$

$t = 39.9$ h

9. The ratio of the radius of a classical electron (2.8×10^{-15} m) to the radius of a ^4He nucleus is

A) 2.0 B) 0.68 C) 1.47 D) 0.92 E) 2.4

$R_{He} = 1.2 * 10^{-15} * \sqrt[3]{4}$

$\frac{R_e}{R_{He}} = \frac{2.8 * 10^{-15}}{1.2 * 10^{-15} * \sqrt[3]{4}}$

$= 1.47$

10. A certain isotope has a half-life of 32.4 hour and a relative biological effectiveness of 3.50. A sample of this isotope initially delivers an absorbed dose of 0.240 Gy to 250 g of tissue.
(a) What was the initial equivalent dose to the tissue in rem and in Sv? 84 rem, 0.84 Sv
(b) What energy (in J) did the 250-g sample initially receive from the isotope? 0.06 J

11. The maximum permissible workday dose for occupational exposure to radiation is 26 mrem. A 55-kg laboratory technician absorbs 3.3 mJ of 0.40-MeV gamma rays in a workday. The relative biological effectiveness (RBE) for gamma rays is 1.00. What is the ratio of the equivalent dosage received by the technician to the maximum permissible equivalent dosage?
A) 0.23 B) 0.25 C) 0.28 D) 0.30 E) 0.32

12. A 70-kg laboratory technician absorbs 2.9 mJ of 0.50-MeV gamma rays in a workday. How many gamma-ray photons does the technician absorb in a workday?
A) 3.6×10^{10} B) 3.6×10^{9} C) 3.6×10^{8} D) 1.0×10^{9} E) 1.0×10^{8}

13. A 57-kg researcher absorbs 6.3×10^{8} neutrons in a workday. The energy of the neutrons is 2.6 MeV. The RBE for fast neutrons is 10. What is the equivalent dosage of the radiation exposure (in mrem) of this worker?
A) 4.6 B) 1.4 C) 2.9 D) 14 E) 46

14. The radioactive nuclei ^{60}Co is widely used in medical applications. It undergoes beta decay, and the total energy of the decay process is 2.82 MeV per decay event. The half-life of this nucleus is 272 days. Suppose that a patient is given a dose of 6.9 µCi of ^{60}Co. If all of this material decayed while in the patient's body, what would be the total energy deposited there? (1 Ci = 3.70×10^{10} decays/s)
A) 11 J B) 8.6 GJ C) 3.9 J D) 24 J E) 4.15 MJ

15. A laboratory experiment uses a 10 µCi ^{137}Cs source. Each decay emits a 0.66 MeV gamma ray. A 60 kg person standing nearby absorbs 10 % of the gamma rays.
(a) What is his absorbed dose in rads in 1 hour? 34×10^{-5} rad
(b) Find his effective dose in rems (take RBE = 0.8). 0.0187 mrem

16. Suppose your last **physical exam** included a chest X-ray, during which you received a dose of 60 µSv.
(a) What was your dose in mrem? 6 mrem
(b) What was the absorbed dose in µGy and mrad? 60 µGy , 6 mrad.
(c) How much energy did you absorb, assuming that the X-rays illuminated 15 kg of your body? 9×10^{-4} J

Hmm... I bet that you prefer to go through 10 of such diagnostic X-ray **physical exams** than being asked to sit for your **"105" physics exam**! Don't you?

10. A certain isotope has a half-life of 32.4 hour and a relative biological effectiveness of 3.50. A sample of this isotope initially delivers an absorbed dose of 0.240 Gy to 250 g of tissue.

(a) What was the initial equivalent dose to the tissue in rem and in Sv? 84 rem, 0.84 Sv

(b) What energy (in J) did the 250-g sample initially receive from the isotops? 0.06 J

$t_{1/2} = 32.4\ h$ $RBE = 3.5$

$AD = 0.24\ Gy$ $m = 0.25\ kg$

a) $ED = 0.24 * 3.5 = 0.84$

b) $0.24\ \frac{J}{kg} * 0.25\ kg = 0.06\ J = 6 * 10^{-2}\ J$

11. The maximum permissible workday dose for occupational exposure to radiation is 26 mrem. A 55-kg laboratory technician absorbs 3.3 mJ of 0.40-MeV gamma rays in a workday. The relative biological effectiveness (RBE) for gamma rays is 1.00. What is the ratio of the equivalent dosage received by the technician to the maximum permissible equivalent dosage?

A) 0.23   B) 0.25   C) 0.28   D) 0.30   E) 0.32

maximum workday dose = 26 mrem

$ED_{technician} = AD * RBE = \frac{3.3 * 10^{-3}}{55} * 1 = 6 * 10^{-5} \rightarrow 6 * 10^{-3}\ rem$

$ED_{max} = 26 * 10^{-3}\ rem$

$\frac{ED}{ED_{max}} = \frac{6 * 10^{-3}}{26 * 10^{-3}} = 0.23$

12. A 70-kg laboratory technician absorbs 2.9 mJ of 0.50-MeV gamma rays in a workday. How many gamma-ray photons does the technician absorb in a workday?

A) 3.6×10^{10} B) 3.6×10^{9} C) 3.6×10^{8} D) 1.0×10^{9} E) 1.0×10^{8}

total energy = energy of gamma * number of photon

$2.9 \times 10^{-3} = 0.5 * 10^{6} * 1.66 * 10^{-19} * N$

$\therefore N = 3.5 * 10^{10}$

13. A 57-kg researcher absorbs 6.3 × 10^8 neutrons in a workday. The energy of the neutrons is 2.6 MeV. The RBE for fast neutrons is 10. What is the equivalent dosage of the radiation exposure (in mrem) of this worker? A) 4.6 B) 1.4 C) 2.9 D) 14 E) 46

$$AD = \frac{6.3 \times 10^8 \times 2.6 \times 10^6 \times 1.6 \times 10^{-19}}{57} = 4.6 \times 10^{-6}\ Gy = 4.6 \times 10^{-4}\ rad$$

$$ED = 4.6 \times 10^{-4} \times 10 = 4.6 \times 10^{-3}\ rem = 4.6\ mrem$$

14. The radioactive nuclei ^{60}Co is widely used in medical applications. It undergoes beta decay, and the total energy of the decay process is 2.82 MeV per decay event. The half-life of this nucleus is 272 days. Suppose that a patient is given a dose of 6.9 µCi of ^{60}Co. If all of this material decayed while in the patient's body, what would be the total energy deposited there? (1 Ci = 3.70 × 10^{10} decays/s)

A) 11 J B) 8.6 GJ C) 3.9 J D) 24 J E) 4.15 MJ

$t_{1/2} = 272$

$$A_o = \lambda N_o$$

$$6.9 \times 10^{-6} \times 3.7 \times 10^{10} = 2.95 \times 10^{-8} \times N_o$$

$$\therefore N_o = 8.7 \times 10^{12}\ \text{decay}$$

$$\lambda = \frac{\ln(2)}{272 \times 24 \times 60 \times 60}$$

$$\lambda = 2.95 \times 10^{-8}$$

2.82 MeV → 1 decay

x → 8.7×10^{12}

$$x = 2.4 \times 10^{13}\ MeV \rightarrow 3.9\ J$$

15. A laboratory experiment uses a 10 µCi ^{137}Cs source. Each decay emits a 0.66 MeV gamma ray. A 60 kg person standing nearby absorbs 10 % of the gamma rays.

(a) What is his absorbed dose in rads in 1 hour?

(b) Find his effective dose in rems (take RBE = 0.8).

$1.1 \times 10^{-13}\ J$

$$A_o = 10 \times 10^{-6} \times 3.7 \times 10^{10} = 3.7 \times 10^5\ Bq$$

$$A)\ E_{tot} = 1.1 \times 10^{-13} \times 3.7 \times 10^5 = 4.07 \times 10^{-8}\ \frac{J}{s}$$

$$AD = \frac{4.07 \times 10^{-8}\ \frac{J}{s} \times 0.1}{60\ kg} = 6.78 \times 10^{-11}\ \frac{Gy}{s} = 6.78 \times 10^{-9}\ \frac{rad}{s}$$

$6.78 \times 10^{-9} \longrightarrow 1\ s$

$X \longrightarrow 3600\ s$

$\therefore X = 2.4 \times 10^{-7}$ rad

B) $ED = 2.4 \times 10^{-7} \times 0.8 = 1.87 \times 10^{-5}$ rem

16. Suppose your last **physical exam** included a chest X-ray, during which you received a dose of 60 μSv.

(a) What was your dose in mrem? $60 \times 10^{-6} \times 100$ rem $\longrightarrow$ 6 mrem

(b) What was the absorbed dose in μGy and mrad? 60 μGy / 6 mrad

(c) How much energy did you absorb, assuming that the X-rays illuminated 15 kg of your body? energy $= AD \times 15 = 60 \times 10^{-6} \times 15 = 900 \times 10^{-6}$

$= 9 \times 10^{-4}$