Physics 25 Practice Problems Chapters 31 and 32

1. At 1:00 pm today there are 1600 micro-grams of a radioactive substance whose half-life is 30 minutes. How many micro-grams will there be at 3:00 pm today?

2. After 40 days, a 2000-gram radioactive substance decays to only 125 grams. What is the half-life of this substance?

3. A bone unearthed on an archaeological dig is analyzed for its carbon content. It is found that for every carbon-14 nucleus, there are 32 trillion carbon-12 nuclei. How many years ago was this the bone of a living animal?

4. A radioactive nucleus whose atomic number is 83, and which has 112 neutrons, decays sequentially, first by alpha-emission, then by two beta-particle emissions. What is the atomic weight of the resulting nucleus?

5. The half-life of a radioactive substance is 20 days. Right now, there are 900 picograms (900×10^{-12} g). How many picograms will remain after 53 days?

6. Twenty-four hours ago there were 4000 grams of an unstable isotope of uranium. Now, there are 178 grams. After about how much more hours, starting now, will there be only 33 grams?

7. Radium-231 (${}_{88}Ra^{231}$) undergoes several decays, and at each stage, a different element is created: alpha decay, neutron emission, another alpha decay, and finally, beta-particle emission. What is the atomic number (Z) and atomic mass number (A) of the resulting nucleus?

8. What is the radius (in cm) of a solid sphere of uranium-235 that will release 3.0×10^{14} J (four Hiroshima bombs) of energy if only five percent of it undergoes fission? The density of uranium is 19.1 g/cm^3. Also note: one mole of any atomic substance is Avogadro's Number of atoms: 6.02×10^{23} atoms, and furthermore one mole of an atomic substance equals its atomic mass (in this case, 235 grams).

9. How close (in meters) could a 75-kg person be to a 6.0 watt radioactive source in order to receive a dose of 500 rads in three hours, while facing the source? Assume the person's effective area facing the source is 0.80 m^2.

Solutions

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<td>1. From 1:00 pm to 3:00 pm there are 120 minutes, or four times 30 minutes, which is four half-lives, four halvings:

$1600 \rightarrow 800 \rightarrow 400 \rightarrow 200 \rightarrow 100$ μg</td>
<td>2. $2000 \rightarrow 1000 \rightarrow 500 \rightarrow 250 \rightarrow 125$ g
Four halvings, four half-lives:
$4T = 40$ days
$T = 10$ days</td>
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<td rowspan="2">3. $1 \rightarrow 2 \rightarrow 4 \rightarrow 8 \rightarrow 16 \rightarrow 32$
Five doublings of C-12/C-14 ratio occurred because there were five halvings of C-14 while the C-12 content was unchanged, which means five half-lives had gone by since the animal died:

5(5730) = 28,650 years ago the animal died</td>
<td>4. ${}_{83}X^{195} \rightarrow {}_{2}\alpha^{4} + {}_{-1}\beta^{0} + {}_{-1}\beta^{0} + {}_{83}Y^{191}$</td>
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<td>5. Decay constant $\lambda = 0.693/20$
$= 0.0347 \text{ day}^{-1}$

$M = 900\, e^{-0.0347(53)}$
$= 143$ pg</td>
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<td>6. $178 = 4000\, e^{-\lambda(24)}$
$\lambda = 0.130 \text{ hr}^{-1}$
$33 = 178\, e^{-0.130t}$
$t = 13$ hrs</td>
<td>7. ${}_{88}Ra^{231} \rightarrow {}_{2}\alpha^{4} + {}_{0}n^{1} + {}_{2}\alpha^{4} + {}_{-1}\beta^{0} + {}_{85}At^{222}$
Atomic Number (Z) = 85
Atomic Mass Number (A) = 222</td>
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<td colspan="2">8. $(3 \times 10^{14}$ J$) / (1.98 \times 10^{-11}$ J/nucleus$) = 1.52 \times 10^{25}$ nuclei
Multiply by 20 to account for only 5% efficiency:

$20\,(1.52 \times 10^{25}) = 3.04 \times 10^{26}$
$n = (3.04 \times 10^{26}) / 6.02 \times 10^{23}$
$= 504.98$ moles
$m = (504.98$ moles$)\,(235$ g/mole$)$
$= 118{,}671$ g
$V = (118{,}670$ g$) / (19.1$ g/cm$^3)$
$= 6213$ cm^3
$(4/3)\pi\, r^3 = 6213$
$r = 11.40$ cm</td>
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9. Dose = 500 rad
= 5.00 J/kg
m = 75 kg
E = (75 kg)(5.00 J/kg)
= 375 J
t = 3 hours
= 10,800 s
P_A = 375 /10,800
= 0.0347 watts

$P_A = (A/4\pi r^2)\ P$
$0.0347 = (0.80/4\pi r^2)\ 6.0$
r = 3.3 m