Homework 7   Radioactivity

1. How many protons and how many neutrons are in (a) 3 He, (b) 32 P, (c) 32 S, and (d) 238 U?

2. How many protons and how many neutrons are in (a) 6 Li, (b) 54 Cr, (c) 54 Fe, and (d) 220 Rn?

3. The half-life of ^{131}I is 8.04 days. On a certain day, the activity of an iodine-131 sample is 6.40 mCi. What is its activity 40.2 days later?

4. A freshly prepared sample of a certain radioactive isotope has an activity of 10.0 mCi. After 4.00 h, its activity is 8.00 mCi. (a) Find the decay constant and half-life. (b) How many atoms of the isotope were contained in the freshly prepared sample? (c) What is the sample's activity 30.0 h after it is prepared?

5. A sample of radioactive material contains 1.00×10^{15} atoms and has an activity of 6.00×10^{11} Bq. What is its half-life?

6. A radioactive nucleus has half-life $T_{1/2}$. A sample containing these nuclei has initial activity R_0 . Calculate the number of nuclei that decay during the interval between the times t_1 and t_2.

7. The half-life of a particular radioactive isotope is 6.5 h. If there are initially 48 x 10^{19} atoms of this isotope, how many atoms of this isotope remain after 26 h?

8. A radioactive isotope of mercury, ^{197}Hg, decays into gold, ^{197}Au, with a disintegration constant of 0.0108 h^{-1}. (a) What is its half-life? (b) What fraction of the original amount will remain after three half-lives? (c) What fraction will remain after 10.0 days?

9. The radionuclide ^{64}Cu has a half-life of 12.7 h. How much of an initially pure, 5.50-g sample of ^{64}Cu will decay during the 2.0-h period beginning 14.0 h later?

10. In an experiment on the transport of nutrients in the root structure of a plant, two radioactive nuclides X and Y are used. Initially 2.50 times more nuclei of type X are present than of type Y. Just three days later there are 4.20 times more nuclei of type X than of type Y. Isotope Y has a half-life of 1.60 d. What is the half-life of isotope X?

11. Find the energy released in the alpha decay

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

Table B.3 in your text might be useful.

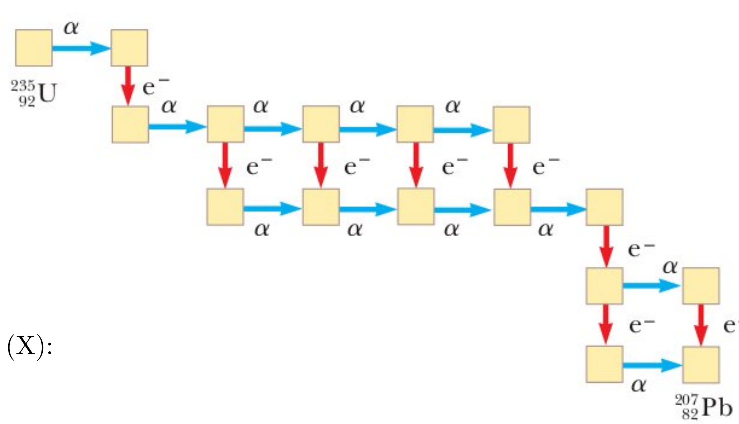
12. Identify the missing nuclide or particle (X):

   (a) $\mathrm{X} + {}^{4}_{2}\mathrm{He} \rightarrow {}^{24}_{12}\mathrm{Mg} + {}^{1}_{0}\mathrm{n}$

   (b) $^{235}_{92}\mathrm{U} + {}^{24}_{12}\mathrm{Mg} + {}^{1}_{0}\mathrm{n} \rightarrow {}^{90}_{38}\mathrm{Sr} + \mathrm{X} + 2{}^{1}_{0}\mathrm{n}$

   (c) $2{}^{1}_{1}\mathrm{H} \rightarrow {}^{2}_{1}\mathrm{H} + \mathrm{X} + \mathrm{X}'$

13. Enter the correct isotope symbol in each open square in the figure which shows the sequences of decays in the natural radioactive series starting with the long-lived isotope uranium-235 and ending with the stable nucleus lead-207.



14. Identify the missing nuclide or particle (X):

   (a) $\mathrm{X} \rightarrow {}^{65}_{28}\mathrm{Ni} + \gamma$

(b) ${}^{215}_{84}\mathrm{Po} \rightarrow \mathrm{X} + {}^{4}_{2}\mathrm{He}$

(c) $\mathrm{X} \rightarrow {}^{55}_{26}\mathrm{Fe} + \mathrm{e}^{+} + \nu$

(d) ${}^{14}_{7}\mathrm{N} + {}^{4}_{2}\mathrm{He} \rightarrow \mathrm{X} + {}^{18}_{8}\mathrm{O}$

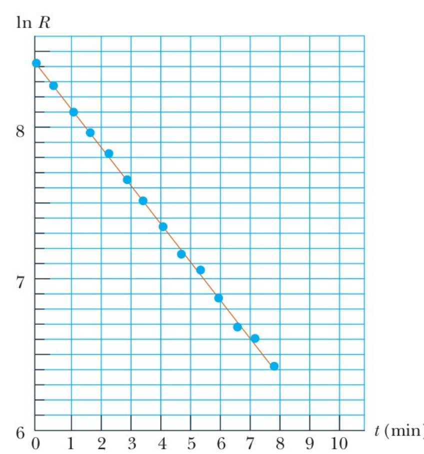
15. As part of his discovery of the neutron in 1932, Chadwick determined the mass of the newly identified particle by firing a beam of fast neutrons, all having the same speed, at two different targets and measuring the maximum recoil speeds of the target nuclei. The maximum speeds arise when an elastic head-on collision occurs between a neutron and a stationary target nucleus. (a) Represent the masses and final speeds of the two target nuclei as m_1, v_1, m_2, and v_2 and assume that Newtonian mechanics applies. Show that the neutron mass can be calculated from the equation

$$m_n = \frac{m_1 v_1 - m_2 v_2}{v_2 - v_1}$$

(b) Chadwick directed a beam of neutrons (produced from a nuclear reaction) on paraffin, which contains hydrogen. The maximum speed of the protons ejected was found to be $3.3 \times 10^7\ m/s$. Because the velocity of the neutrons could not be determined directly, a second experiment was performed using neutrons from the same source and nitrogen nuclei as the target. The maximum recoil speed of the nitrogen nuclei was found to be $4.7 \times 10^6\ m/s$. The masses of a proton and a nitrogen nucleus were taken as 1 u and 14 u, respectively. What was Chadwick's value for the neutron mass?

16. After the sudden release of radioactivity from the Chernobyl nuclear reactor accident in 1986, the radioactivity of milk in Poland rose to 1500 Bq/L due to iodine-131 present in the grass eaten by dairy cattle. Radioactive iodine, with half-life $t_I = 8.04\ days$, is particularly hazardous because the thyroid gland concentrates iodine. The Chernobyl accident caused a measurable increase in thyroid cancers among children in Belarus. (a) For comparison, find the activity of milk due to potassium. Assume that one liter of milk contains a mass $m_K = 2.5\ g$ of potassium, of which a fraction $f = 0.0117\%$ is the isotope ${}^{40}\mathrm{K}$ with half-life $t_K = 1.28 \times 10^9\ yr$. (b) After what time interval would the activity due to iodine fall below that due to potassium?

17. The radioactive barium isotope ${}^{137}Ba$ has a relatively short half-life and can be easily extracted from a solution containing its parent cesium (${}^{137}\mathrm{Cs}$). This barium isotope is commonly used in an undergraduate laboratory exercise for demonstrating the radioactive decay law. Undergraduate students using modest experimental equipment took the data presented in the figure. Determine the half-life for the decay of ${}^{137}Ba$ using their data.



18. On August 6, 1945, the United States dropped on Hiroshima a nuclear bomb that released $5 \times 10^{13}\ J$ of energy, equivalent to that from 12000 tons of TNT. The fission of one ${}^{235}_{92}U$ nucleus releases an average of 208 MeV. Estimate (a) the number of nuclei fissioned and (b) the mass of this ${}^{235}_{92}U$.

19. How many half-lives must elapse until (a) 90% and (b) 99% of a radioactive sample of atoms has decayed?

20. A sample contains radioactive atoms of two types, A and B. Initially there are five times as many A atoms as there are B atoms. Two hours later, the numbers of the two atoms are equal. The half-life of A is 0.50 hour. What is the half-life of B?

21. The technique known as potassium-argon dating is used to date old lava flows. The potassium isotope ${}^{40}\mathrm{K}$ has a 1.28 billion year half-life and is naturally present at very low levels. ${}^{40}\mathrm{K}$ decays by two routes: 89% undergo beta-minus decay into ${}^{40}\mathrm{Ca}$ while 11% undergo electron capture to become ${}^{40}\mathrm{Ar}$. Argon is a gas, and there is no argon in flowing lava because the gas escapes. Once the lava solidifies, any argon produced in the decay of ${}^{40}\mathrm{K}$ is trapped inside and cannot escape. A geologist brings you a piece of solidified lava in which you find the ${}^{40}\mathrm{Ar}/{}^{40}\mathrm{K}$ ratio to be 0.013. What is the age of the rock?

22. The half-life of the uranium isotope ^{235}U is 700 million years. The earth is approximately 4.5 billion years old. How much more ^{235}U was there when the earth formed than there is today? Give your answer as the then-to-now ratio.