

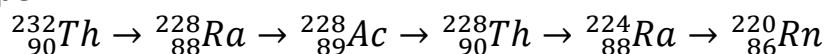
Nuclear Physics Problems Set

Radioactive Decay

1. Write the nuclear reaction equation for the following nuclei undergoing the indicated type of decay:

| | Nucleus | Decay type |
|----|----------------|---------------------|
| a. | Polonium-210 | alpha decay |
| b. | Calcium-45 | beta-negative decay |
| c. | Chromium-46 | beta-positive decay |
| d. | Dysprosium-152 | γ decay |
| e. | Plutonium-240 | α decay |
| f. | Copper-58 | gamma decay |
| g. | Bismuth-214 | β^- decay |
| h. | Sodium-22 | β^+ decay |

2. The following shows the products of part of a decay series known as the Thorium Series. Write a nuclear reaction equation for each decay stage of the series and identify its type.



Half-life, Carbon Dating

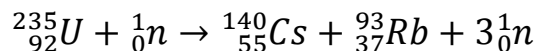
3. To which of the following objects, each about 1000 yr old, can the radiocarbon dating technique not be applied: a wooden box, a gold statue, and some plant seeds? Explain.
4. Some preserved seed were found and their age, through the technique of carbon dating, was determined to be 5000 years old. However, new evidence suggests that the amount of carbon in the air at that time is higher than previously thought. Are the seeds older or younger than 5000 years? Explain.
5. The half-life of carbon-14 is 5730 a. An ancient piece of bark is estimated to have originally contained 2.00 μg of carbon-14. If its age has been determined to be 1.7×10^4 a, how much carbon-14 does it now have?
6. A specimen of peat from an ancient bog contains 800.0 μg of carbon-14. What will be the amount of carbon-14 remaining after 1.0×10^4 a?

7. Uranium-238 has a half-life of 4.468×10^9 a. A sample of uranium ore currently has 722 mg of uranium-238. If the sample is 5.9×10^8 a, how much uranium-238 was there when it formed?
8. Iodine $^{131}_{53}I$ is used in diagnostic and therapeutic techniques in the treatment of thyroid disorders. This isotope has a half-life of 8.04 days. What percentage of an initial sample of $^{131}_{53}I$ remains after 30.0 days?
9. To make the dial of a watch glow in the dark, 1.000×10^{-9} kg of radium $^{226}_{88}Ra$ is used. The half-life of this isotope has a value of 1.60×10^3 yr. How many kilograms of radium *disappear* while the watch is in use for fifty years?
10. The shroud of Turin is a religious artefact known since the Middle Ages. In 1988 its age was measured using the radiocarbon dating technique, which revealed that the shroud could not have been made before 1200 AD. Of the $^{14}_6C$ nuclei that were present in the living matter from which the shroud was made, what percentage remained in 1988?

Nuclear Fission

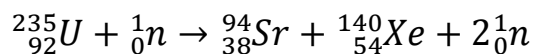
11. During a nuclear reaction, an unknown particle is absorbed by a copper $^{63}_{29}Cu$ nucleus, and the reaction products are $^{62}_{29}Cu$, a neutron, and a proton. What is the name, atomic number, and nucleon number of the nucleus formed temporarily when the copper $^{63}_{29}Cu$ nucleus absorbs the unknown particle?
12. A neutron causes $^{232}_{90}Th$ to fission according to the reaction
- $$^{232}_{90}Th + {}^1_0n \rightarrow {}^A_ZX + \gamma$$
- Identify the unknown nucleus, giving its atomic mass number A , its atomic number Z , and the symbol X for the element.
 - Nucleus X then undergoes β^- decay, and its daughter does too. Identify the final nucleus, giving its atomic mass number, atomic number, and name.
13. A small sample of coal, when completely converted to energy, releases 4.5×10^{14} J of energy. Determine the original mass of coal, assuming the final mass is zero.

14. Calculate the mass defect, in kilograms, and the energy released, in joules, of the following nuclear reaction:



$${}_{92}^{235}\text{U} = 235.044 \text{ u}, \quad {}_0^1\text{n} = 1.009 \text{ u}, \quad {}_{55}^{140}\text{Cs} = 139.909 \text{ u}, \quad {}_{37}^{93}\text{Rb} = 92.922 \text{ u}$$

15. How much energy, in MeV, is released by the following fission reaction?



$${}_{92}^{235}\text{U} = 235.044 \text{ u}, \quad {}_0^1\text{n} = 1.009 \text{ u}, \quad {}_{38}^{94}\text{Sr} = 93.915 \text{ u}, \quad {}_{54}^{140}\text{Xe} = 139.922 \text{ u}$$

16. The energy released during each ${}_{92}^{235}\text{U}$ fission is 2.0×10^2 MeV. How many kilograms of coal must be burned to produce the same energy as 1.0 kg of ${}_{92}^{235}\text{U}$ if 3.0×10^7 J of energy is released when 1.0 kg of coal is burned? (n.b. 2.6×10^{24} U nuclei are found in a 1 kg sample of uranium)

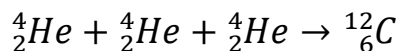
Nuclear Fusion

17. Compare and contrast nuclear fission and fusion. How are they alike? How are they different?

18. Explain why nuclear fusion is much more difficult to obtain than nuclear fission

19. Why is nuclear fusion more desirable than nuclear fission for power generation? Explain.

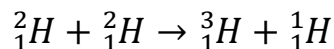
20. One reaction to produce carbon in stars is as follows:



Calculate the mass defect, in atomic mass units, and energy released, in electronvolts, of this reaction. (${}^4_2\text{He} m = 4.002603 \text{ u}$, ${}^{12}_6\text{C} m = 12.000000 \text{ u}$)

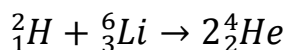
21. Consider the induced nuclear reaction ${}^2_1\text{H} + {}^{14}_7\text{N} \rightarrow {}^{12}_6\text{C} + {}^4_2\text{He}$. The atomic masses are ${}^2_1\text{H}$ (2.014 102 u), ${}^{14}_7\text{N}$ (14.003 074 u), ${}^{12}_6\text{C}$ (12.000 000 u), and ${}^4_2\text{He}$ (4.002 603 u). Determine the energy released, in joules, when the ${}^{12}_6\text{C}$ and ${}^4_2\text{He}$ nuclei are formed in this way.

22. Two deuterium atoms (${}^2_1\text{H} = 2.014102 \text{ u}$) react to produce tritium (${}^3_1\text{H} = 3.016050 \text{ u}$) and hydrogen (${}^1_1\text{H} = 1.007825 \text{ u}$) according to the reaction:

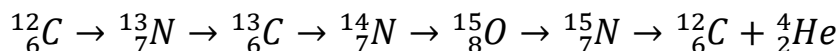


What is the energy released by this deuterium-deuterium reaction?

23. One proposed fusion reaction combines lithium ${}^6_3\text{Li}$ (6.015 u) with deuterium ${}^2_1\text{H}$ (2.014 u) to give helium ${}^4_2\text{He}$ (4.003 u):



- a) How many of the above reactions would need to occur to supply the energy needs of one household for a year (estimated to be $3.8 \times 10^{10} \text{ J}$)?
- b) How many grams of lithium would be needed if there are 8.673×10^{25} Li nuclei in 1 kg of a lithium sample?
24. The following shows the carbon-nitrogen-oxygen (CNO) cycle that occurs inside stars. Write a nuclear reaction equation for each stage in the cycle and identify its type.



Answers

- | | |
|--------------------------------------|---------------------------------------------------------------------------|
| 5. 0.25 μg | 13. 5.0 g |
| 6. 240 μg | 14. $3.237 \times 10^{-28} \text{ kg}$, $2.91 \times 10^{-11} \text{ J}$ |
| 7. 790 mg | 15. 184 MeV |
| 8. 7.53 % | 16. $2.8 \times 10^6 \text{ kg}$ |
| 9. $2.14 \times 10^{-11} \text{ kg}$ | 20. $7.8 \times 10^{-3} \text{ u}$, 7.25 MeV |
| 10. 91 % | 21. $2.163418 \times 10^{-12} \text{ J}$ |
| 11. ${}^{64}_{30}\text{Zn}$ | 22. $2.17896 \times 10^{-12} \text{ J}$ |
| 12. a) ${}^{232}_{90}\text{Th}$ | 23. a) $1.11 \times 10^{22} \text{ reactions}$ |
| b) ${}^{233}_{92}\text{U}$ | b) 0.13 g |