Problems

30–1 Nuclear Properties

1. (I) A pi meson has a mass of 139 MeV/c^2. What is this in atomic mass units?

2. (I) What is the approximate radius of an alpha particle ($^4_2$He)?

3. (II) What is the rest mass of a bare α particle in MeV/c^2?

4. (II) (*a*) What is the approximate radius of a $^{64}_{29}$Cu nucleus? (*b*) Approximately what is the value of A for a nucleus whose radius is 3.9×10^{-15} m?

5. (II) (*a*) Show that the density of nuclear matter is essentially the same for all nuclei. (*b*) What would be the radius of the Earth if it had its actual mass but had the density of nuclei? (*c*) What would be the radius of a $^{238}_{92}$U nucleus if it had the density of the Earth?

6. (II) (*a*) What is the fraction of the hydrogen atom's mass that is in the nucleus? (*b*) What is the fraction of the hydrogen atom's volume that is occupied by the nucleus?

7. (II) Approximately how many nucleons are there in a 1.0-kg object? Does it matter what the object is made of? Why or why not?

8. (III) How much energy must an α particle have to just "touch" the surface of a $^{238}_{92}$U nucleus?

30–2 Binding Energy

9. (I) Estimate the total binding energy for $^{40}_{20}$Ca, using Fig. 30–1.

10. (I) Use Fig. 30–1 to estimate the total binding energy of (*a*) $^{238}_{92}$U, and (*b*) $^{84}_{36}$Kr.

11. (II) Use Appendix B to calculate the binding energy of $^2_1$H (deuterium).

12. (II) Calculate the binding energy per nucleon for a $^{14}_{7}$N nucleus.

13. (II) Determine the binding energy of the last neutron in a $^{40}_{19}$K nucleus.

14. (II) Calculate the total binding energy, and the binding energy per nucleon, for (*a*) $^6_3$Li, (*b*) $^{208}_{82}$Pb. Use Appendix B.

15. (II) Compare the average binding energy of a nucleon in $^{23}_{11}$Na to that in $^{24}_{11}$Na.

16. (III) How much energy is required to remove (*a*) a proton, (*b*) a neutron, from $^{16}_{8}$O? Explain the difference in your answers.

17. (III) (*a*) Show that the nucleus $^8_4$Be (mass = 8.005305 u) is unstable and will decay into two α particles. (*b*) Is $^{12}_{6}$C stable against decay into three α particles? Show why or why not.

30–3 to 30–7 Radioactive Decay

18. (I) How much energy is released when tritium, $^3_1$H, decays by β^- emission?

19. (I) What is the maximum kinetic energy of an electron emitted in the β decay of a free neutron?

20. (I) Show that the decay $^{11}_{6}\text{C} \rightarrow {}^{10}_{5}\text{B} + \text{p}$ is not possible because energy would not be conserved.

21. (II) $^{22}_{11}$Na is radioactive. (*a*) Is it a β^- or β^+ emitter? (*b*) Write down the decay reaction, and estimate the maximum kinetic energy of the emitted β.

22. (II) Give the result of a calculation that shows whether or not the following decays are possible:

    (*a*) $^{236}_{92}\text{U} \rightarrow {}^{235}_{92}\text{U} + \text{n}$;

    (*b*) $^{16}_{8}\text{O} \rightarrow {}^{15}_{8}\text{O} + \text{n}$;

    (*c*) $^{23}_{11}\text{Na} \rightarrow {}^{22}_{11}\text{Na} + \text{n}$.

23. (II) A $^{238}_{92}$U nucleus emits an α particle with kinetic energy = 4.20 MeV. (*a*) What is the daughter nucleus, and (*b*) what is the approximate atomic mass (in u) of the daughter atom? Ignore recoil of the daughter nucleus.

24. (II) When $^{23}_{10}$Ne (mass = 22.9945 u) decays to $^{23}_{11}$Na (mass = 22.9898 u), what is the maximum kinetic energy of the emitted electron? What is its minimum energy? What is the energy of the neutrino in each case? Ignore recoil of the daughter nucleus.

25. (II) A nucleus of mass 238 u, initially at rest, emits an α particle with a KE of 5.0 MeV. What is the KE of the recoiling daughter nucleus?

26. (II) What is the maximum KE of the emitted β particle during the decay of $^{60}_{27}$Co?

27. (II) The nuclide $^{32}_{15}$P decays by emitting an electron whose maximum kinetic energy can be 1.71 MeV. (*a*) What is the daughter nucleus? (*b*) Calculate the daughter's atomic mass (in u).

28. (II) The isotope $^{218}_{84}$Po can decay by either α or β^- emission. What is the energy release in each case? The mass of $^{218}_{84}$Po is 218.008965 u.

29. (II) How much energy is released in electron capture by beryllium: $^7_4\text{Be} + {}^{\;0}_{-1}\text{e} \rightarrow {}^7_3\text{Li} + \nu$?

30. (II) A photon with a wavelength of 1.00×10^{-13} m is ejected from an atom. Calculate its energy and explain why it is a γ ray from the nucleus or a photon from the atom.

31. (II) Determine the maximum kinetic energy of β^+ particles released when $^{11}_{6}$C decays to $^{11}_{5}$B. What is the maximum energy the neutrino can have? What is its minimum energy?

32. (II) How much recoil energy does a $^{40}_{19}$K nucleus get when it emits a 1.46-MeV gamma ray?

33. (III) What is the energy of the α particle emitted in the decay $^{210}_{84}\text{Po} \rightarrow {}^{206}_{82}\text{Pb} + \alpha$? Take into account the recoil of the daughter nucleus.

34. (III) The α particle emitted when $^{238}_{92}$U decays has 4.20 MeV of kinetic energy. Calculate the recoil kinetic energy of the daughter nucleus and the Q-value of the decay.

35. (III) Show that when a nucleus decays by β^+ decay, the total energy released is equal to

    $$(M_\text{P} - M_\text{D} - 2m_\text{e})c^2,$$

    where M_P and M_D are the masses of the parent and daughter atoms (neutral), and m_e is the mass of an electron or positron.