1. Do today's nuclear power plants use fission, fusion, or both?
2. Why doesn't uranium ore spontaneously undergo a chain reaction?
3. Some heavy nuclei, containing even more protons than the uranium nucleus, undergo "spontaneous fission," splitting apart without absorbing a neutron. Why is spontaneous fission observed only in the heaviest nuclei?
4. Why will nuclear fission probably not be used directly for powering automobiles? How could it be used indirectly to power automobiles?
5. Why does a neutron make a better nuclear bullet than a proton?
6. Why will the escape of neutrons be proportionally less in a large piece of fissionable material than in a smaller piece?
7. A 56-kg sphere of U-235 constitutes a critical mass. If the sphere were flattened into a pancake shape, would it still be critical? Explain.
8. Which shape is likely to need more material for a critical mass, a cube or a sphere? Explain.
9. Does the average distance that a neutron travels through fissionable material before escaping increase or decrease when two pieces of fissionable material are assembled into one piece? Does this assembly increase or decrease the probability of an explosion?
10. U-235 releases an average of 2.5 neutrons per fission, while Pu-239 releases an average of 2.7 neutrons per fission. Which of these elements might you therefore expect to have the smaller critical mass?
11. Uranium and thorium occur abundantly in various ore deposits. However, plutonium could occur only in exceedingly tiny amounts in such deposits. What is your explanation?
12. Why, after a uranium fuel rod reaches the end of its fuel cycle (typically 3 years), does most of its energy come from the fissioning of plutonium?
13. If a nucleus of $^{232}_{90}\text{Th}$ absorbs a neutron and the resulting nucleus undergoes two successive beta decays (emitting electrons), what nucleus results?
14. The water that passes through the reactor core of a water-moderated fission reactor does not pass into the turbine. Instead, heat is transferred to a separate water cycle that is entirely outside the reactor. Why is this done?
15. Why is carbon better than lead as a moderator in nuclear reactors?
16. Is the mass of an atomic nucleus greater or less than the sum of the masses of the nucleons composing it? Why don't the nucleon masses add up to the total nuclear mass?
17. The energy release of nuclear fission is tied to the fact that the heaviest nuclei have about 0.1% more mass per nucleon than nuclei near the middle of the periodic table of the elements. What would be the effect on energy release if the 0.1% figure were instead 1%?
18. In what way are fission and fusion reactions similar? What are the main differences in these reactions?
19. How is chemical burning similar to nuclear fusion?
20. To predict the approximate energy release of either a fission reaction or a fusion reaction, explain how a physicist makes use of the curve in Figure 34.16 or a table of nuclear masses and the equation $E = mc^2$.
21. What nuclei will result if a U-235 nucleus, after absorbing a neutron and becoming U-236, splits into two identical fragments?
22. Heavy nuclei can be made to fuse—for instance, by firing one gold nucleus at another one. Does such a process yield energy or cost energy? Explain.
23. Light nuclei can be split. For example, a deuteron, which is a proton–neutron combination, can split into a separate proton and separate neutron. Does such a process yield energy or cost energy? Explain.
24. Which process would release energy from gold, fission or fusion? Which would release energy from carbon? From iron?
25. If uranium were to split into three segments of equal size instead of two, would more energy or less energy be released? Defend your answer in terms of Figure 34.16.
26. Mixing copper and zinc atoms produces the alloy brass. What would be produced with the fusion of copper and zinc nuclei?
27. Oxygen and hydrogen atoms combine to form water. If the nuclei in a water molecule were fused, what element would be produced?
28. If a pair of carbon atoms were fused, and the product were to emit a beta particle, what element would be produced?
29. Suppose the curve in Figure 34.16 for mass per nucleon versus atomic number had the shape of the curve in Figure 34.15. Then would nuclear fission reactions produce energy? Would nuclear fusion reactions produce energy? Defend your answers.
30. The "hydrogen magnets" in Figure 34.20 weigh more when apart than when combined. What would be the basic difference if the fictitious example instead consisted of "nuclear magnets" half as heavy as uranium?
31. In a nuclear fission reaction, which has more mass, the initial uranium or its products?
32. In a nuclear fusion reaction, which has more mass, the initial hydrogen isotopes or the fusion products?
33. Which produces more energy, the fissioning of a single uranium nucleus or the fusing of a pair of deuterium nuclei? The fissioning of a gram of uranium or the fusing of a gram of deuterium? (Why do your answers differ?)
34. Why is there, unlike fission fuel, no limit to the amount of fusion fuel that can be safely stored in one locality?
35. If a fusion reaction produces no appreciable radioactive isotopes, why does a hydrogen bomb produce significant radioactive fallout?
36. List at least two major potential advantages of power production by fusion rather than by fission.
37. Sustained nuclear fusion has yet to be achieved and remains a hope for abundant future energy. Yet the energy that has always sustained us has been the energy of nuclear fusion. Explain.
38. Explain how radioactive decay has always warmed Earth from the inside and how nuclear fusion has always warmed Earth from the outside.
39. The world has never been the same since the discovery of electromagnetic induction and its applications to electric motors and generators. Speculate and list some of the worldwide changes that are likely to follow the advent of successful fusion reactors.
40. Discuss, and make a comparison of, pollution by conventional fossil-fuel power plants and nuclear-fission power plants. Consider thermal pollution, chemical pollution, and radioactive pollution.
41. Ordinary hydrogen is sometimes called a perfect fuel, both because of its almost unlimited supply on Earth and because, when it burns, harmless water is the product of the combustion. So why don't we abandon fission and fusion energies, not to mention fossil-fuel energy, and just use hydrogen?
42. If U-238 splits into two even pieces, and each piece emits an alpha particle, what elements are produced?
43. The energy of fission is mainly in the kinetic energy of its products. What becomes of this energy in a commercial power reactor?
44. Fermi's original reactor was just "barely" critical because the natural uranium that he used contained less than 1% of the fissionable isotope U-235 (half-life 713 million years). What if, in 1942, Earth had been 9 billion years old instead of 4.5 billion years old. Would Fermi have been able to make a reactor go critical with natural uranium?
45. U-235 has a half-life of about 700 million years. What does this say about the likelihood of fission power on Earth 1 billion years from now?