

Chapter 43: ENERGY FROM THE NUCLEUS

1. Consider the following energies:

1. minimum energy needed to excite a hydrogen atom
2. energy needed to ionize a hydrogen atom
3. energy released in ^{235}U fission
4. energy needed to remove a neutron from a ^{12}C nucleus

Rank them in order of increasing value.

- A. 1, 2, 3, 4
- B. 1, 3, 2, 4
- C. 1, 2, 4, 3
- D. 2, 1, 4, 3
- E. 2, 4, 1, 3

ans: C

Section: 43-1; Difficulty: E

2. If the nucleus of a lead atom were broken into two identical nuclei, the total mass of the resultant nuclei would be:

- A. the same as before
- B. greater than before
- C. less than before
- D. converted into radiation
- E. converted into kinetic energy

ans: C

Section: 43-2; Difficulty: E

3. The binding energy per nucleon:

- A. increases for all fission events
- B. increases for some, but not all, fission events
- C. decreases for all fission events
- D. decreases for some, but not all, fission events
- E. remains the same for all fission events

ans: A

Section: 43-2; Difficulty: E

4. When uranium undergoes fission as a result of neutron bombardment, the energy released is due to:

- A. oxidation of the uranium
- B. kinetic energy of the bombarding neutrons
- C. radioactivity of the uranium nucleus
- D. radioactivity of the fission products
- E. a reduction in binding energy

ans: E

Section: 43-2; Difficulty: E

5. The energy supplied by a thermal neutron in a fission event is essentially its:
- A. excitation energy
 - B. binding energy
 - C. kinetic energy
 - D. rest energy
 - E. electric potential energy
- ans: B
Section: 43–2; Difficulty: E
6. When ^{236}U fissions the fragments are:
- A. always ^{140}Xe and ^{94}Sr
 - B. always identical
 - C. never ^{140}Xe and ^{94}Sr
 - D. never identical
 - E. none of the above
- ans: E
Section: 43–2; Difficulty: E
7. Fission fragments usually decay by emitting:
- A. alpha particles
 - B. electrons and neutrinos
 - C. positrons and neutrinos
 - D. only neutrons
 - E. only electrons
- ans: B
Section: 43–2; Difficulty: E
8. When ^{236}U fissions, the products might be:
- A. ^{146}Ba , ^{89}Kr , and a proton
 - B. ^{146}Ba , ^{89}Kr , and a neutron
 - C. ^{148}Cs and ^{85}Br
 - D. ^{133}I , ^{92}Sr , and an alpha particle
 - E. two uranium nuclei
- ans: B
Section: 43–2; Difficulty: E
9. Consider all possible fission events. Which of the following statements is true?
- A. Light initial fragments have more protons than neutrons and heavy initial fragments have fewer protons than neutrons
 - B. Heavy initial fragments have more protons than neutrons and light initial fragments have fewer protons than neutrons
 - C. All initial fragments have more protons than neutrons
 - D. All initial fragments have about the same number of protons and neutrons
 - E. All initial fragments have more neutrons than protons
- ans: E
Section: 43–2; Difficulty: E

10. Which one of the following represents a fission reaction that can be activated by slow neutrons?

- A. $^{238}\text{U}_{92} + {}^1_0\text{n} \rightarrow {}^{90}\text{Kr}_{36} + {}^{146}\text{Cs}_{55} + {}^2_1\text{H} + {}^1_0\text{n}$
- B. $^{239}\text{Pu}_{94} + {}^1_0\text{n} \rightarrow {}^{96}\text{Sr}_{38} + {}^{141}\text{Ba}_{56} + 3 {}^1_0\text{n}$
- C. $^{238}\text{U}_{92} \rightarrow {}^{234}\text{Th}_{90} + {}^4_2\text{He}$
- D. ${}^3_1\text{H} + {}^2_1\text{H} \rightarrow {}^4_2\text{He} + {}^1_0\text{n}$
- E. $^{107}\text{Ag}_{47} + {}^1_0\text{n} \rightarrow {}^{108}\text{Ag}_{47} \rightarrow {}^{108}\text{Cd}_{48} + {}^0_{-1}\text{e}$

ans: B

Section: 43-2; Difficulty: M

11. In the uranium disintegration series:

- A. the emission of a β^- particle increases the mass number A by one and decreases the atomic number Z by one
- B. the disintegrating element merely ejects atomic electrons
- C. the emission of an α particle decreases the mass number A by four and decreases the atomic number Z by two
- D. the nucleus always remains unaffected
- E. the series of disintegrations continues until an element having eight outermost orbital electrons is obtained

ans: C

Section: 43-2; Difficulty: E

12. The barrier to fission comes about because the fragments:

- A. attract each other via the strong nuclear force
- B. repel each other electrically
- C. produce magnetic fields
- D. have large masses
- E. attract electrons electrically

ans: A

Section: 43-3; Difficulty: E

13. ^{235}U is readily made fissionable by a thermal neutron but ^{238}U is not because:

- A. the neutron has a smaller binding energy in ^{236}U
- B. the neutron has a smaller excitation energy in ^{236}U
- C. the potential barrier for the fragments is less in ^{239}U
- D. the neutron binding energy is greater than the barrier height for ^{236}U and less than the barrier height for ^{239}U
- E. the neutron binding energy is less than the barrier height for ^{236}U and greater than the barrier height for ^{239}U

ans: D

Section: 43-3; Difficulty: E

14. An explosion does not result from a small piece of ^{235}U because:
- A. it does not fission
 - B. the neutrons released move too fast
 - C. ^{238}U is required
 - D. too many neutrons escape, preventing a chain reaction from starting
 - E. a few neutrons must be injected to start the chain reaction
- ans: D
Section: 43–3; Difficulty: E
15. Separation of the isotopes of uranium requires a physical, rather than chemical, method because:
- A. mixing other chemicals with uranium is too dangerous
 - B. the isotopes are chemically the same
 - C. the isotopes have exactly the same number of neutrons per nucleus
 - D. natural uranium contains only 0.7% ^{235}U
 - E. uranium is the heaviest element in nature
- ans: B
Section: 43–4; Difficulty: E
16. Which one of the following is NOT needed in a nuclear fission reactor?
- A. Moderator
 - B. Fuel
 - C. Coolant
 - D. Control device
 - E. Accelerator
- ans: E
Section: 43–4; Difficulty: E
17. The function of the control rods in a nuclear reactor is to:
- A. increase fission by slowing down the neutrons
 - B. decrease the energy of the neutrons without absorbing them
 - C. increase the ability of the neutrons to cause fission
 - D. decrease fission by absorbing neutrons
 - E. provide the critical mass for the fission reaction
- ans: D
Section: 43–4; Difficulty: E
18. A nuclear reactor is operating at a certain power level, with its multiplication factor adjusted to unity. The control rods are now used to reduce the power output to one-half its former value. After the reduction in power the multiplication factor is maintained at:
- A. $1/2$
 - B. $1/4$
 - C. 2
 - D. 4
 - E. 1
- ans: E
Section: 43–4; Difficulty: E

19. The purpose of a moderator in a nuclear reactor is to:
- A. provide neutrons for the fission process
 - B. slow down fast neutrons to increase the probability of capture by uranium
 - C. absorb dangerous gamma radiation
 - D. shield the reactor operator from dangerous radiation
 - E. none of the above
- ans: B
Section: 43–4; Difficulty: E
20. In a neutron-induced fission process, delayed neutrons come from:
- A. the fission products
 - B. the original nucleus just before it absorbs the neutron
 - C. the original nucleus just after it absorbs the neutron
 - D. the moderator material
 - E. the control rods
- ans: A
Section: 43–4; Difficulty: E
21. In a nuclear reactor the fissionable fuel is formed into pellets rather than finely ground and the pellets are mixed with the moderator. This reduces the probability of:
- A. non-fissioning absorption of neutrons
 - B. loss of neutrons through the reactor container
 - C. absorption of two neutrons by single fissionable nucleus
 - D. loss of neutrons in the control rods
 - E. none of the above
- ans: A
Section: 43–4; Difficulty: E
22. In a subcritical nuclear reactor:
- A. the number of fission events per unit time decreases with time
 - B. the number of fission events per unit time increases with time
 - C. each fission event produces fewer neutrons than when the reactor is critical
 - D. each fission event produces more neutrons than when the reactor is critical
 - E. none of the above
- ans: A
Section: 43–4; Difficulty: E
23. In the normal operation of a nuclear reactor:
- A. control rods are adjusted so the reactor is subcritical
 - B. control rods are adjusted so the reactor is critical
 - C. the moderating fluid is drained
 - D. the moderating fluid is continually recycled
 - E. none of the above
- ans: B
Section: 43–4; Difficulty: E

24. In a nuclear power plant, the power discharged to the environment:
- A. can be made zero by proper design
 - B. must be less than the electrical power generated
 - C. must be greater than the electrical power generated
 - D. can be entirely recycled to produce an equal amount of electrical power
 - E. is not any of the above

ans: E

Section: 43–4; Difficulty: E

25. The binding energy per nucleon:
- A. increases for all fusion events
 - B. increases for some, but not all, fusion events
 - C. remains the same for some fusion events
 - D. decreases for all fusion events
 - E. decreases for some, but not all, fusion events

ans: A

Section: 43–6; Difficulty: E

26. To produce energy by fusion of two nuclei, the nuclei must:
- A. have at least several thousand electron volts of kinetic energy
 - B. both be above iron in mass number
 - C. have more neutrons than protons
 - D. be unstable
 - E. be magic number nuclei

ans: A

Section: 43–6; Difficulty: E

27. Which one of the following represents a fusion reaction that yields large amounts of energy?

- A. $^{238}\text{U}_{92} + ^1_0\text{n} \rightarrow ^{90}\text{Kr}_{36} + ^{146}\text{Cs}_{55} + ^2_1\text{H} + ^1_0\text{n}$
- B. $^{239}\text{Pu}_{92} + ^1_0\text{n} \rightarrow ^{96}\text{Sr}_{38} + ^{141}\text{Ba}_{56} + 3^1_0\text{n}$
- C. $^{238}\text{U}_{92} \rightarrow ^{234}\text{Th}_{90} + ^4_2\text{He}$
- D. $^3_1\text{H} + ^2_1\text{H} \rightarrow ^4_2\text{He} + ^1_0\text{n}$
- E. $^{107}\text{Ag}_{47} + ^1_0\text{n} \rightarrow ^{108}\text{Ag}_{47} \rightarrow ^{108}\text{Cd}_{48} + ^0_{-1}\text{e}$

ans: D

Section: 43–6; Difficulty: M

28. The barrier to fusion comes about because protons:
- A. attract each other via the strong nuclear force
 - B. repel each other electrically
 - C. produce magnetic fields
 - D. attract neutrons via the strong nuclear force
 - E. attract electrons electrically

ans: B

Section: 43–6; Difficulty: E

29. High temperatures are required in thermonuclear fusion so that:
- A. some nuclei are moving fast enough to overcome the barrier to fusion
 - B. there is a high probability some nuclei will strike each other head on
 - C. the atoms are ionized
 - D. thermal expansion gives the nuclei more room
 - E. the uncertainty principle can be circumvented

ans: A

Section: 43–6; Difficulty: E

30. Most of the energy produced by the Sun is due to:
- A. nuclear fission
 - B. nuclear fusion
 - C. chemical reaction
 - D. gravitational collapse
 - E. induced emfs associated with the Sun's magnetic field

ans: B

Section: 43–7; Difficulty: E

31. Nuclear fusion in stars produces all the chemical elements with mass numbers less than:
- A. 56
 - B. 66
 - C. 70
 - D. 82
 - E. 92

ans: A

Section: 43–7; Difficulty: E

32. Nuclear fusion in the Sun is increasing its supply of:
- A. hydrogen
 - B. helium
 - C. nucleons
 - D. positrons
 - E. neutrons

ans: B

Section: 43–7; Difficulty: E

33. Which of the following chemical elements is not produced by thermonuclear fusion in stars?
- A. Carbon ($Z = 6$, $A \approx 12$)
 - B. Silicon ($Z = 14$, $A \approx 28$)
 - C. Oxygen ($Z = 8$, $A \approx 16$)
 - D. Mercury ($Z = 80$, $A \approx 200$)
 - E. Chromium ($Z = 24$, $A \approx 52$)

ans: D

Section: 43–7; Difficulty: E

34. The first step of the proton-proton cycle is:

- A. ${}^1\text{H} + {}^1\text{H} \rightarrow {}^2\text{H}$
- B. ${}^1\text{H} + {}^1\text{H} \rightarrow {}^2\text{H} + e^+ + \nu$
- C. ${}^1\text{H} + {}^1\text{H} \rightarrow {}^2\text{H} + e^- + \nu$
- D. ${}^1\text{H} + {}^1\text{H} \rightarrow {}^2\text{H} + \gamma$
- E. ${}^1\text{H} + {}^1\text{H} \rightarrow {}^3\text{H} + e^- + \nu$

ans: B

Section: 43-7; Difficulty: E

35. The overall proton-proton cycle is equivalent to:

- A. $2 {}^1\text{H} \rightarrow {}^2\text{H}$
- B. $4 {}^1\text{H} \rightarrow {}^4\text{H}$
- C. $4 {}^1\text{H} \rightarrow {}^4\text{H} + 4\text{n}$
- D. $4 {}^1\text{H} + 2e^- \rightarrow {}^4\text{He} + 2\nu + 6\gamma$
- E. $4 {}^1\text{H} + 2e^+ \rightarrow {}^4\text{He} + 2\nu + 3\gamma$

ans: D

Section: 43-7; Difficulty: E

36. The energy released in a complete proton-proton cycle is about:

- A. 3 keV
- B. 30 keV
- C. 3 MeV
- D. 30 MeV
- E. 300 MeV

ans: D

Section: 43-7; Difficulty: E

37. For a controlled nuclear fusion reaction, one needs:

- A. high number density n and high temperature T
- B. high number density n and low temperature T
- C. low number density n and high temperature T
- D. low number density n and low temperature T
- E. high number density n and temperature $T = 0\text{ K}$

ans: A

Section: 43-8; Difficulty: E

38. For purposes of a practical (energy producing) reaction one wants a disintegration energy Q that is:

- A. positive for fusion reactions and negative for fission reactions
- B. negative for fusion reactions and positive for fission reactions
- C. negative for both fusion and fission reactions
- D. positive for both fusion and fission reactions
- E. as close to zero as possible for both fusion and fission reactions

ans: D

Section: 43-8; Difficulty: E

39. Lawson's number is $10^{20} \text{ s} \cdot \text{m}^{-3}$. If the density of deuteron nuclei is $2 \times 10^{21} \text{ m}^{-3}$ what should the confinement time be to achieve sustained fusion?
- A. 16 ms
 - B. 50 ms
 - C. 160 ms
 - D. 250 ms
 - E. 500 ms
- ans: B
Section: 43–8; Difficulty: E
40. Tokamaks confine deuteron plasmas using:
- A. thick steel walls
 - B. magnetic fields
 - C. laser beams
 - D. vacuum tubes
 - E. electric fields
- ans: B
Section: 43–8; Difficulty: E
41. Most magnetic confinement projects attempt:
- A. proton-proton fusion
 - B. proton-deuteron fusion
 - C. deuteron-deuteron fusion
 - D. deuteron-triton fusion
 - E. triton-triton fusion
- ans: C
Section: 43–8; Difficulty: E
42. Compared to fusion in a tokamak, laser fusion makes use of:
- A. smaller particle number densities
 - B. greater particle number densities
 - C. longer confinement times
 - D. higher temperatures
 - E. lower temperatures
- ans: B
Section: 43–8; Difficulty: E
43. Most laser fusion projects attempt:
- A. proton-proton fusion
 - B. proton-deuteron fusion
 - C. deuteron-deuteron fusion
 - D. deuteron-triton fusion
 - E. triton-triton fusion
- ans: D
Section: 43–8; Difficulty: E

44. In laser fusion, the laser light is:
- A. emitted by the reacting nuclei
 - B. used to cause transitions between nuclear energy levels
 - C. used to cause transitions between atomic energy levels
 - D. used to replace the emitted gamma rays
 - E. used to heat the fuel pellet

ans: E

Section: 43–8; Difficulty: E