***Physics: Principle and Applications*, 7e (Giancoli)**
Chapter 31   Nuclear Energy; Effects and Uses of Radiation

31.1   Conceptual Questions

1) A person receives an absorbed dose of protons of 20 millirads. The RBE of protons is 5. What is this person's equivalent dose in rem?
A) 4 millirem
B) 15 millirem
C) 20 millirem
D) 25 millirem
E) 100 millirem
Answer: E
Var: 1

2) The chief hazard of radiation damage to living cells is
A) due to heating.
B) due to ionization.
C) due to the creation of chemical impurities.
D) the creation of new isotopes within the body.
E) the creation of radioactive material within the body.
Answer: B
Var: 1

3) What is the meaning of the term "critical mass" in regard to nuclear fission?
A) This is the mass of the "critical" elements in a reactor, i.e., the uranium or plutonium.
B) This is the minimum amount of fissionable material required to sustain a chain reaction.
C) This is the amount of mass needed to make a power reactor economically feasible.
D) This is the amount of material that is just on the verge of becoming radioactive.
Answer: B
Var: 1

4) The main fuel for producing energy in the center of the sun is
A) helium.
B) hydrogen.
C) uranium.
D) any radioactive material.
E) oxygen.
Answer: B
Var: 1

5) The energy radiated by a star, such as the sun, results chiefly from
A) beta decay.
B) alpha decay.
C) fission reactions.
D) fusion reactions.
E) radioactivity.
Answer: D
Var: 1

31.2 Problems

1) The maximum permissible workday dose for occupational exposure to radiation is 18 mrem. A 54-kg laboratory technician absorbs 2.6 mJ of 0.30-MeV gamma rays in a work day. The relative biological effectiveness (RBE) for gamma rays is 1.00. What is the ratio of the equivalent dosage received by the technician to the maximum permissible equivalent dosage?
A) 0.27
B) 0.29
C) 0.32
D) 0.35
E) 0.37
Answer: A
Var: 50+

2) The maximum permissible workday dose for occupational exposure to radiation is 11 mrem. A 77-kg laboratory technician absorbs 2.3 mJ of 0.5-MeV gamma rays in a work day. The relative biological effectiveness (RBE) for gamma rays is 1.00. What is the number of gamma-ray photons absorbed by the technician in a workday?
A) 3×10^{10}
B) 3×10^{9}
C) 3×10^{8}
D) 1×10^{9}
E) 1×10^{8}
Answer: A
Var: 50+

3) A 70-kg researcher absorbs 4.5×10^{8} neutrons in a work day, each of energy 1.2 MeV. The relative biological effectiveness (RBE) for these neutrons is 10. What is the equivalent dosage of the radiation exposure for this researcher, in millirem?
A) 1.2 mrem
B) 0.39 mrem
C) 0.77 mrem
D) 3.7 mrem
E) 12 mrem
Answer: A
Var: 50+

4) Determine the missing product X in the nuclear reaction ${}^{238}_{92}\text{U} + {}^{1}_{0}\text{n} \rightarrow \text{X} + 2\beta^{-}$.

Answer: ${}^{239}_{94}\text{Pu}$

Var: 1

5) Determine the missing product X in the following nuclear reaction:
${}^{16}_{8}\text{O}$ + neutron → X + alpha particle

Answer: ${}^{13}_{6}\text{C}$

Var: 1

6) Determine the missing product X in the following nuclear reaction:
${}^{235}_{92}\text{U}$ + neutron → ${}^{141}_{56}\text{Ba}$ + X + 3 neutrons

Answer: ${}^{92}_{36}\text{Kr}$

Var: 1

7) Determine the missing product X in the following nuclear reaction:
${}^{10}_{5}\text{B}$ + neutron → X + alpha particle

Answer: ${}^{7}_{3}\text{Li}$

Var: 1

8) Determine the missing product X in the following nuclear reaction:
${}^{13}_{7}\text{N}$ + neutron → X + alpha particle

Answer: ${}^{10}_{5}\text{B}$

Var: 1

9) The equation shows a fission reaction:
${}^{235}_{92}\text{U} + {}^{1}_{0}\text{n} \rightarrow {}^{99}_{41}\text{Nb} + \text{X} + 4\,{}^{1}_{0}\text{n}$
What is the missing term X in the equation?
A) ${}^{136}_{47}\text{Ag}$

B) ${}^{136}_{51}\text{Sb}$

C) ${}^{139}_{51}\text{Sb}$

D) ${}^{133}_{47}\text{Ag}$

E) ${}^{133}_{51}\text{Sb}$

Answer: E
Var: 1

10) In the fission reaction $^{235}U + ^{1}n \rightarrow ^{141}Ba + ^{92}Kr + x\ ^{1}n$, what is the number x of neutrons produced?
A) 0
B) 1
C) 2
D) 3
Answer: D
Var: 1

11) In the nuclear reaction $^{16}_{8}O + ^{4}_{2}He \rightarrow X + ^{19}_{10}Ne$, what is X?

A) proton
B) neutron
C) ^{2}H
D) ^{3}H
E) alpha particle
Answer: B
Var: 1

12) In the nuclear reaction $^{16}_{8}O + ^{1}_{0}n \rightarrow X + ^{4}_{2}He$, what is X?

A) ^{12}C
B) ^{13}C
C) ^{14}C
D) ^{15}C
E) ^{17}O
Answer: B
Var: 1

13) In the nuclear reaction $^{38}_{19}K + ^{1}_{1}H \rightarrow X + ^{38}_{20}Ca$, what is X?

A) proton
B) neutron
C) ^{2}H
D) ^{3}H
E) alpha particle
Answer: B
Var: 1

14) In the nuclear reaction ${}^{3}_{1}H + {}^{3}_{1}H \rightarrow X + {}^{4}_{2}He$, what is X?

A) 2 protons
B) 2 neutrons
C) ${}^{2}H$
D) ${}^{3}H$
E) alpha particle
Answer: B
Var: 1

15) A proton strikes an oxygen-18 nucleus, producing fluorine-18 and another particle X. What is the other particle X?
A) neutron
B) positron
C) alpha particle
D) electron
E) gamma ray
Answer: A
Var: 1

16) A hypothetical particle has a mass of 510 MeV/c^2. If such a particle at rest decays into two gamma-ray photons, what is the wavelength of each photon? (1 eV = 1.60×10^{-19} J, $c = 3.00 \times 10^{8}$ m/s, $h = 6.626 \times 10^{-34}$ J· s)
Answer: 4.87×10^{-15} m
Var: 1

17) If a Σ^- particle at rest decays into a neutron and a π^- , what is the total kinetic energy of the decay products? The masses of Σ^-, neutron, and π^- are 1197 MeV/c^2, 940 MeV/c^2, and 140 MeV/c^2, respectively.
Answer: 117 MeV
Var: 1

18) Consider the fusion reaction:
$^{2}_{1}H + ^{2}_{1}H + ^{2}_{1}H \rightarrow ^{4}_{2}He + ^{1}_{1}H + ^{1}_{0}n$

The know atomic masses are

$^{2}_{1}H$:	2.01410 u
$^{4}_{2}He$:	4.00260 u
$^{1}_{1}H$:	1.00783 u
$^{1}_{0}n$:	1.008665 u

where 1 u = 1.6605 × 10-27 kg. What mass of deuterium fuel, $^{2}_{1}H$, is used up in producing 5.6×10^{15} J of energy by this reaction?
Answer: 1.6×10^{1} kg
Var: 50+

19) Consider the nuclear reaction $^{14}_{7}N + ^{4}_{2}He \rightarrow ^{17}_{8}O + ^{1}_{1}H$. The known atomic masses are

$^{14}_{7}N$:	14.003074 u
$^{4}_{2}He$:	4.002603 u
$^{1}_{1}H$:	1.007825 u
$^{17}_{8}O$:	16.999131 u

What is the *Q*-value (or reaction energy) of this reaction? (1 u = 931.5 MeV/c^2)
A) -1.191 MeV
B) -2.020 MeV
C) -6.725 MeV
D) -9.055 MeV
Answer: A
Var: 1

20) Consider the nuclear reaction: ^{7}Li + ^{1}p → ^{4}He + ^{4}He. The known atomic masses are

^{7}Li: 7.016005 u

$^4_2$He: 4.002603 u

^{1}p: 1.007825 u

What is the *Q*-value (or reaction energy) of this reaction? (1 u = 931.5 MeV/c^2)
A) 13.57 MeV
B) 15.37 MeV
C) 17.35 MeV
D) 17.53 MeV
Answer: C
Var: 1

21) Consider the nuclear reaction $^{14}_{7}$N + $^4_2$He → $^{17}_{8}$O + $^1_1$H. The known atomic masses are

$^{14}_{7}$N: 14.003074 u

$^4_2$He: 4.002603 u

$^1_1$H: 1.007825 u

$^{17}_{8}$O: 16.999131 u

What is the *Q*-value (or reaction energy) of this reaction? (1 u = 931.5 MeV/c^2)
A) 1.191 MeV
B) -1.191 MeV
C) 1.279×10^{-3} MeV
D) -1.279×10^{-3} MeV
Answer: B
Var: 1

22) Consider the nuclear reaction $^3_1$H + $^3_1$H → $^4_2$He + 2 $^1_0$n. The known atomic masses are

$^4_2$He: 4.002603 u

$^3_1$H: 3.016049u

$^1_0$n: 1.008665 u

What is the energy released (positive) or absorbed (negative) in this nuclear reaction? (1 u = 931.5 MeV/c^2)
A) 0.0122 MeV
B) -0.0122 MeV
C) 11.3 MeV
D) -11.3 MeV
Answer: C
Var: 1

23) A nuclear explosion results in a mass decrease of 2.10 g. How much energy is released during this explosion? ($c = 3.00 \times 10^8$ m/s)
A) 1.89×10^{14} J
B) 6.30×10^5 J
C) 1.89×10^{13} J
D) 2.25×10^{12} J
Answer: A
Var: 28

24) An electron and a positron, both essentially at rest, annihilate each other, emitting two identical photons in the process. What is the wavelength of these photons? The mass of an electron or positron is 9.11×10^{-31} kg. ($h = 6.626 \times 10^{-34}$ J · s, $c = 3.00 \times 10^8$ m/s)
A) 1.21×10^{-12} pm
B) 1.73 pm
C) 2.42 pm
D) 3.07 pm
E) 3.46 pm
Answer: C
Var: 1

25) An excited $^{236}_{92}U^*$ nucleus undergoes fission into two fragments as follows:

$^{236}_{92}U^* \rightarrow {}^{144}_{56}Ba + {}^{92}_{36}Kr$

The following atomic masses are known:

$^{92}_{36}Kr$: 91.926270 u

$^{144}_{56}Ba$: 143.922845 u

$^{236}_{92}U^*$: 236.045563 u

What is the reaction energy released during this fission reaction? (1 u = 931.5 MeV/c^2)
A) 150 MeV
B) 160 MeV
C) 170 MeV
D) 180 MeV
E) 190 MeV
Answer: D
Var: 1

26) When a neutron collides with a uranium-235 nucleus it can induce a variety of fission reactions. One such reaction is
$^{235}_{92}U + ^{1}_{0}n \rightarrow ^{140}_{54}Xe + ^{94}_{38}Sr + 2\,^{1}_{0}n$

The following mass values are known:

$^{140}_{54}Xe$: 139.921620 u

$^{94}_{38}Sr$: 93.915367 u

$^{235}_{92}U$: 235.043924 u

$^{1}_{0}n$: 1.008665 u

How much energy is released in this reaction? (1 u = 931.5 MeV/c^2)
A) 185 MeV
B) 202 MeV
C) 32.6 MeV
D) 65.7 MeV
E) 98.6 MeV
Answer: A
Var: 1

27) When a neutron collides with a uranium-235 nucleus it can induce a variety of fission reactions. One such reaction is
$^{235}_{92}U + ^{1}_{0}n \rightarrow ^{140}_{54}Xe + ^{94}_{38}Sr + 2\,^{1}_{0}n$

The following mass values are known:

$^{140}_{54}Xe$: 139.921620 u

$^{94}_{38}Sr$: 93.915367 u

$^{235}_{92}U$: 235.043924 u

$^{1}_{0}n$: 1.008665 u

What mass of uranium is needed to produce a 10-kiloton yield? (1 u = 931.5 MeV/c^2 = 1.66054 × 10^{-27} kg, 1-kiloton yield = 5.0 × 10^{12} J)
A) 0.57 kg
B) 0.66 kg
C) 6.58 kg
D) 3.85 kg
E) 1.10 kg
Answer: B
Var: 1

28) Two deuterium nuclei, ${}^{2}_{1}H$, fuse to produce a tritium nucleus, ${}^{3}_{1}H$, plus an ordinary hydrogen nucleus, ${}^{1}_{1}H$. A neutral deuterium atom has a mass of 2.014102 u; a neutral tritium atom has a mass of 3.016050 u; a neutral hydrogen atom has a mass of 1.007825 u; a neutron has a mass of 1.008665 u; and a proton has a mass of 1.007277 u. How much energy is released in this fusion process? (1 u = 931.5 MeV/c^2)
A) 3.03 MeV
B) 3.53 MeV
C) 4.03 MeV
D) 4.53 MeV
E) 6.58 MeV
Answer: C
Var: 1

29) If a 2.0-MeV neutron released in a fission reaction loses half its kinetic energy in each moderator collision, how many collisions are needed to reduce its kinetic energy to 1/25 eV?
A) 6
B) 18
C) 26
D) 30
E) 4
Answer: C
Var: 1

30) If a nuclear fission reactor produces an average power of 1.0 GW over the course of a year, what mass of ${}^{235}U$ is used up for a 365-day year if 200 MeV are released per fission reaction? (1 eV = 1.60 × 10^{-19} J, $m_{neutron} \approx m_{proton}$ = 1.67 × 10-27 kg)
A) 0.35 kg
B) 1.75 kg
C) 390 kg
D) 1.1 × 10^{8} kg
E) 3.3 × 10^{8} kg
Answer: C
Var: 1

31) When ${}^{235}U$ undergoes fission, the average energy per fission event is 200 MeV. How much energy is released in the total fission of 2.0 g of ${}^{235}U$? (1 eV = 1.60 × 10^{-19} J, $m_{neutron} \approx m_{proton}$ = 1.67 × 10-27 kg)
A) 1.6 × 10^{11} J
B) 3.9 × 10^{13} J
C) 1.6 × 10^{5} J
D) 3.9 × 10^{10} J
Answer: A
Var: 6