Chapter 2: Physics of Nuclear Medicine
Test Bank

MULTIPLE CHOICE

1. An atom is:
   a. the smallest quantity of an element that retains all the chemical properties of that element
   b. can be broken into smaller particles to combine with other elements
   c. the smallest particle of a chemical compound that retains all the chemical properties of that element
   d. a form of electromagnetic radiation

   ANS: A
   An atom is the smallest quantity of an element (e.g., hydrogen, carbon) that retains all the chemical properties of that element. Atoms cannot be broken into smaller particles.

   REF: p. 45

2. The smallest particle of a chemical compound that retains all the chemical properties is a(n):
   a. atom
   b. isotope
   c. element
   d. molecule

   ANS: D
   Two or more atoms may combine to form a molecule. A molecule is the smallest particle of a chemical compound that retains all the chemical characteristics of that compound.

   REF: p. 45

3. The part of the atom that is responsible for all chemical interactions with other atoms is:
   a. the proton
   b. the neutron
   c. the outermost electrons
   d. the innermost electrons

   ANS: C
   The extranuclear region of the atom is the area outside the nucleus. This region of the atom, specifically the outermost electrons, is responsible for all chemical interactions with other atoms and is the area in which most of the interactions of radiation and matter occur.

   REF: p. 45

4. When using the standard notation in the physical sciences for representing elements with a one- or two-letter chemical name symbol, the letter *Z* represents the:
   a. atomic mass
   b. atomic number
   c. number of neutrons
   d. number of electrons

ANS: B
The total number of protons in an atom is the atomic number, symbolized by the letter *Z*, and is unique for each element.

REF: p. 46

5. If indium has an atomic number of 49 and an atomic mass of 112, how many neutrons are found in a stable element of indium-112?
   a. 14
   b. 49
   c. 63
   d. 112

   ANS: C
   Z is the element's atomic number (number of protons), and *A* represents the atomic mass number of the atom (protons plus neutrons). Although the number of neutrons can be indicated as a trailing subscript number, it is usually not written because it can be calculated by subtracting *Z* from *A.*

   REF: p. 49

6. Isotopes are different forms of a specific element that have:
   a. a different number of protons
   b. a different number of neutrons
   c. a different number of electrons
   d. a different number of atomic mass

   ANS: B
   The term *isotope* defines a specific element with different forms of that element each containing different numbers of neutrons. The isotopes will follow a horizontal line on the chart of the nuclides (e.g., ^{97}Tc, ^{98}Tc, ^{99}Tc, ^{100}Tc, and ^{101}Tc).

   REF: p. 49

7. Which of the following is <u>*not*</u> true of isotopes?
   a. They have the same atomic number.
   b. They have the same mass number.
   c. They have the same number of neutrons.
   d. They have the same chemical properties.

   ANS: C
   The same element will always have a specific number of protons as listed by the atomic number *Z* and will have the same chemical properties; however, the number of neutrons can differ. These atoms with different numbers of neutrons are isotopes. The word *isotope* comes from the Greek words *iso* (meaning "*same"*) and *topos* (meaning "*place"*), indicating that the atoms have the same position on the periodic table of elements.

   REF: p. 49

8. Atoms that have identical physical attributes but a different amount of nuclear energy are called:
   a. isotones

b. isotopes
c. isomers
d. isobars

ANS: C
Isomers are atoms that have identical physical attributes, such as the number of protons, neutrons, and electrons; however, they contain a different amount of nuclear energy.

REF: p. 49

9. ^{98}Mo, ^{99}Tc, and ^{100}Ru are examples of:
a. isotopes
b. isotones
c. isomers
d. isobars

ANS: B
Isotones are atoms of different elements that have the same number of neutrons but varying numbers of protons. ^{98}Mo, ^{99}Tc, and ^{100}Ru are isotones: all having 56 neutrons and forming a vertical line on the chart of the nuclides.

REF: p. 49

10. The alpha particles consist of:
a. one proton and two neutrons
b. two protons and one neutron
c. two protons and two neutrons
d. two protons and three neutrons

ANS: C
Alpha particles (helium nuclei consisting of two protons and two neutrons) are radioactive decay products from radionuclides having a large, unstable mass.

REF: p. 49

11. When an unstable element undergoes a radioactive decay process resulting in a new element, the process is called**:**
a. conversion
b. transition
c. isolation
d. transmutation

ANS: D
The formation of a different element by a radioactive decay process is called **transmutation,** or *isobaric radioactive decay.*

REF: p. 51

12. After beta-minus decay of iodine, which has an atomic number of 131 and an atomic mass of 53, the resultant nuclide will the following mass number (A) and atomic number (Z):
a. (A) = 131, (Z) = 52
b. (A) = 131, (Z) = 54

c. $(A) = 130$, $(Z) = 53$
d. $(A) = 132$, $(Z) = 53$

ANS: D
This nuclear decay process is termed beta-minus or simply beta decay. The parent element *M* with atomic number *Z* and mass number *A* decays by beta emission as:

$${}_{53}^{131}\mathrm{I} \rightarrow {}_{54}^{131}\mathrm{Xe} + e^{-} + \nu_e$$

REF: p. 51

13. Positron decay comes from the nucleus that is:
    a. proton-rich
    b. neutron-rich
    c. electron-rich
    d. neutrino-rich

    ANS: A
    A nucleus that is proton-rich (neutron-poor) can reduce its proton surplus by two possible decay processes: positron decay or electron capture.

    REF: p. 51

14. When electron capture occurs:
    a. an orbital electron is captured and combined with a proton to form a neutron
    b. a beta-minus electron is recaptured and added to a proton to form a neutron
    c. when there is a transfer of energy from the nucleus to an orbital electron
    d. an orbital electron is captured and converted to a positron

    ANS: A
    Electron capture occurs when an orbital electron travels in the proximity of the nucleus and is captured and combined with a proton to form a neutron. (Answer C describes internal conversion.)

    REF: p. 51

15. Gamma emission usually occurs:
    a. when there is an excess of protons in the excited nucleus
    b. when there is greater than 100 keV of excess energy in the excited nucleus
    c. whenever a K-shell electron is captured.
    d. as particulate radiation to eliminate excess energy from the nucleus

    ANS: B
    Gamma emission usually occurs when there is greater than 100 keV of excess energy in the excited nucleus; it is a mechanism for an excited nucleus to release energy. The gamma ray may be part of another decay process or a release of energy from a metastable nucleus.

    REF: p. 52

16. The transition of ^{99m}Tc to ^{99}Tc is considered to be:
    a. isotonic
    b. isobaric

c. isomeric
d. isotopic

ANS: C
When a metastable nucleus is present, there is a significant amount of time from any previous radioactive decay before a further release of energy. The release from a metastable state is termed an *isomeric transition*. In this transition, the nucleus goes from a higher energy level to a lower energy level through electromagnetic radiation (usually greater than 100 keV); this is sometimes referred to as *gamma decay*.

REF: p. 52

17. Gamma rays differ from x-rays in that they have different:
a. masses
b. charges
c. velocities
d. origins

ANS: D
Gamma rays and x-rays have the same characteristics but the names are based on their origin; gamma rays are emitted from the nucleus and x-rays from the electron shells.

REF: p. 52

18. 10 millicuries is equal to how many megabequerels?
a. 0.37
b. 3.7
c. 37
d. 370

ANS: D
Multiply the number of millicuries by 37 MBq/mCi to convert to the number of megabecquerels. For example, 20 mCi × 37 MBq/mCi = 740 MBq. Conversely, convert the number of megabecquerels to millicuries by dividing by 37 MBq/mCi; for example, 111 MBq/(37 MBq/mCi) = 3 mCi.

REF: p. 56

19. Assuming the biological half-life of ^{99m}Tc-MAA is 3 hours, what would be the effective half-life?
a. 0.3 hour
b. 0.5 hour
c. 2 hours
d. 3 hours

ANS: C
$t_{eff}=\frac{t_{bx} \times t_p}{t_b+t_p}$ where t_{eff} = effective half-life, t_b = biologic half-life, t_p = physical half-life

REF: p. 57

20. Removal of an electron from a neutral atom is called:
   a. excitation
   b. ionization
   c. pairing
   d. bonding

ANS: B
Ionization of an atom results from the collision of radiation with the electron structure of an atom. Ionization occurs only when the radiation has sufficient energy to completely remove an electron from its orbit.

REF: p. 58

21. All of the following are true about bremsstrahlung radiation EXCEPT:
   a. It occurs when a beta particle is deflected and slowed in its path.
   b. There is a low probability of occurrence when shielding beta particles with lead.
   c. Its probability increases when shielding betas with materials that have a high Z number.
   d. It is the method used to produce x-rays in computed tomography (CT) scanners.

ANS: B
As the beta particle is deflected and slowed in its path, there is a release of energy as x-rays, called *bremsstrahlung radiation.* These x-rays are released in a continuous spectrum because of the variations in kinetic energy and path geometry of the beta particle. Bremsstrahlung interactions increase in probability with materials that have a high *Z* number.

REF: p. 58

22. The minimum MeV photon energy required for pair production is:
   a. 0.511
   b. 1.022
   c. 5.110
   d. 10.22

ANS: B
In annihilation process, the rest masses of the positron and negatron are identical (0.511 MeV), giving a total energy of 1.022 MeV.

REF: p. 58

23. For the photoelectric effect to occur, the energy of the incident photon must be:
   a. less than that of the binding energy of the orbital electron
   b. equal to that of the binding energy of the orbital electron
   c. greater than that of the binding energy of the orbital electron
   d. equal to the binding energy minus the photon energy

ANS: C
For the photoelectric effect to occur, the energy of the incident photon must be greater than the binding energy of the orbital electron.

REF: p. 59

24. In the photoelectric process, the energy of the incoming photon:
   a. is completely absorbed
   b. scatters with no change of energy
   c. scatters with a loss of energy
   d. scatters with an increase of energy

   ANS: A
   In the photoelectric effect, the photon energy is completely absorbed with some of its energy used to break the bond of the electron in its shell, and the remaining energy is given to the electron in the form of motion or kinetic energy.

   REF: p. 59

25. The probability of a photoelectric interaction:
   a. increases with low-Z material
   b. increases with high-Z material
   c. is high in tissue
   d. is high in water

   ANS: B
   The probability of a photoelectric interaction occurring depends on the energy of the incident gamma ray and the atomic number of the material. As a photon's energy increases, the probability for photoelectric interactions decreases (see Figure 2-20). The probability of a photoelectric interaction increases dramatically with the atomic number; that is, photoelectric interactions are unlikely to occur in low-*Z* materials such as water and tissue but are likely to occur in high-*Z* materials such as the iodine in a sodium iodide crystal or in lead. The photoelectric effect is therefore the primary type of interaction for detecting gamma rays with nuclear medicine instruments.

   REF: p. 59

26. In Compton scattering, the energy of the emitted electron:
   a. is equal to the energy of the incoming photon
   b. is less than the energy of the incoming photon
   c. is greater than the energy of the incoming photon
   d. is equal to the binding energy of the electron

   ANS: B
   The energy and wavelength of the scattered photon are always lower than those of the incident photon, and the scattered photon's energy also depends on the atomic number of the scattering material, the incident photon's energy, and the angle of the scatter.

   REF: p. 60

27. Pair production is always followed by:
   a. annihilation
   b. Compton scatter
   c. electron capture
   d. the photoelectric effect

   ANS: A

Pair production is an interaction produced when a photon with an energy greater than 1.02 MeV passes near the high-electric field of the nucleus. The strong electrical force brings about the energy-mass conversion. When the photon comes near the nucleus, it disappears totally and two particles of matter are created, an electron and a positron, each possessing the mass equivalence of 0.511 MeV.

REF: p. 60

28. An alternative process to the emission of a characteristic x-ray is:
   a. pair production
   b. photoelectric effect
   c. Compton scatter
   d. Auger effect

ANS: D
Characteristic x-rays are produced as part of the process of reducing excess energy when electrons fill vacancies in the inner shells. An alternative to characteristic x-rays is the Auger effect. In this interaction, the surplus energy is given to another orbital electron that is ejected. The ejected electron is called an *Auger electron* and the atom is left with two vacancies occurring in the electron structure.

REF: p. 61

29. The relationship between the linear attenuation coefficient (u) and the half-value layer (HVL) is given by:
   a. $HVL/\mu = 0.693$
   b. $\mu = 0.693/HVL$
   c. $HVL = 0.693\ \mu$
   d. $HVL\ \mu^2 = 0.693$

ANS: B
The linear attenuation coefficient μ is the probability of attenuation per distance traveled through an absorber. The HVL is the thickness of the absorber necessary to diminish the intensity of the radiation to half its initial strength. The linear attenuation coefficient μ is related to the HVL of the material by: $\mu = 0.693/HVL$.

REF: pp. 61, 62

30. The half-value layer (HVL) for annihilation radiation in lead is 4.1 cm. Approximately, what percentage of a of 511 keV photon beam will penetrate 15 cm of lead?
   a. 50%
   b. 37%
   c. 33%
   d. 25%

ANS: D
The HVL is the thickness of the absorber necessary to diminish the intensity of the radiation to half its initial strength. Because 4.1 cm is equal to one half-value layer, 8 cm is equal to approximately 2 HVLs, thereby diminishing the intensity of radiation to one fourth of the original intensity. The equation is:

$$I = I_0 e^{-0.693x/HVL}$$

REF: p. 57

31. Forms of electromagnetic radiation differ only in frequency and wavelength.
   a. True
   b. False

   ANS: A
   Heat waves, radio waves, infrared light, visible light, ultraviolet light, and x-rays and gamma rays are all forms of electromagnetic radiation (Figure 2-1). They differ only in frequency and wavelength.

   REF: p. 44

32. An electrically neutral atom as the same number of protons and neutrons.
   a. True
   b. False

   ANS: B
   An electrically neutral atom has an equal number of protons and electrons.

   REF: p. 45

33. The total number of protons is referred to as the atomic mass.
   a. True
   b. False

   ANS: B
   The total number of protons in an atom is the atomic number, symbolized by the letter *Z*, and is unique for each element.

   REF: p. 46

34. Electrons can be deflected by an electronic or a magnetic field.
   a. True
   b. False

   ANS: A
   Because electrons carry a negative charge, they are deflected by electric or magnetic fields.

   REF: p. 46

35. An unstable configuration of protons and neutrons is referred to as nuclides.
   a. True
   b. False

   ANS: B
   Any configuration of protons and neutrons forming an atom is called a *nuclide.* Of the approximately 3100 nuclides, most are unstable and spontaneously release energy or subatomic particles in an attempt to reach a more stable state. Approximately 270 of the nuclides are in a stable form, comprising only 83 elements. The remainder of the approximately 3100 nuclides are radioactive and are referred to as *radionuclides.*

REF: p. 48