

**QUIZ: Physics of Nuclear Medicine**  
**Atomic Structure, Radioactive Decay, Interaction of Ionizing Radiation with Matter**

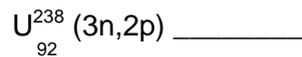
1. An atomic nucleus contains 39 protons and 50 neutrons. Its mass number (A) is
  - a) 39
  - b) 50
  - c) 11
  - d) 89
  - e) None of the above
  
2. In standard notation, one of the isotopes of bromine is  $^{73}_{35}\text{Br}$ . How many neutrons does this nucleus contain?
  - a) 38
  - b) 73
  - c) 35
  - d) 108
  
3. The fundamental particles of greatest interest in the physics of nuclear medicine are the proton, the neutron, and the electron. Of these
  - a) the electron is the least massive and has negative charge
  - b) the proton is the least massive and has negative charge
  - c) the proton is the least massive and has positive charge
  - d) the neutron is the most massive and has positive charge
  
4. A parent nucleus decays by emitting a gamma photon. Parent and daughter nuclei are:
  - a) isotopes
  - b) isotones
  - c) isobars
  - d) isomers
  - e) combination of 2 or more of the above
  
5. Consider the isotope  $^{238}_{92}\text{U}$ . What is
  - \_\_\_\_\_ a) number of protons
  - \_\_\_\_\_ b) number of neutrons
  - \_\_\_\_\_ c) number of electrons
  - \_\_\_\_\_ d) number of nucleons
  - \_\_\_\_\_ e) number of freons
  - \_\_\_\_\_ f) number of positrons
  - \_\_\_\_\_ g) atomic mass
  - \_\_\_\_\_ h) atomic number
  
6. In  $\beta^-$ -decay, which of the following is emitted?
  - a) an ordinary electron
  - b) a positron
  - c) a positron/electron pair
  - d) annihilation radiation

7. The principal types of radiation listed by descending mass are:
- a)  $\gamma, \beta, \alpha$
  - b)  $\beta, \alpha, \gamma$
  - c)  $\alpha, \gamma, \beta$
  - d)  $\alpha, \beta, \gamma$
8. Which of the following represents the ranking, in increasing order of range in air, of  $\alpha$ ,  $\beta$ , and  $\gamma$  rays?
- a)  $\alpha, \beta, \gamma$
  - b)  $\beta, \gamma, \alpha$
  - c)  $\gamma, \beta, \alpha$
  - d) none of the above
9. For an unknown isotope X mark each of the following statements True or False.
- a) The Z number represents the number of electrons
  - b) The Z number represents the number of protons
  - c) The neutrons are represented by (Z-A)
  - d) Electrons in outer orbitals are electrically balanced by positrons in the nucleus
  - e) The mass number  $A = (2Z + N)$
10. Gamma rays are most similar to which one of the following
- a) X-rays
  - b) high speed electrons
  - c) infra-red radiation
  - d) sound waves
  - e) laser beams
11. Answer true or false to these statements regarding Tc-99m
- a) The  $t_{\text{phys}}$  is affected by gravity and heat, but no other environmental factors.
  - b) The predominant gamma ray energy is 140 KeV.
  - c) Technetium isotopes are synthetic; none occur naturally.
  - d) Tc-99m differs from Tc-99g only in terms of nuclear energy levels and  $t_{\text{phys}}$ .

12. Which of the following lists consists of nuclei that are ISOTONES?

- a)  $I^{131}_{53}$   $Xe^{131}_{54}$   $Te^{131}_{52}$   $Sb^{131}_{51}$
- b)  $I^{131}_{53}$   $Xe^{132}_{54}$   $Te^{130}_{52}$   $Sb^{129}_{51}$
- c)  $Cs^{129}_{55}$   $Xe^{129}_{54}$   $I^{129}_{53}$
- d) a and c

13. Predict the Z and A numbers of X, the product of this nuclear reaction:



- a) 92, 239
- b) 90, 239
- c) 92, 238
- d) 90, 238
14. The  $^{99m}\text{Tc}$  nucleus is a metastable state of Tc. This means that
- a) It will decay to  $^{99g}\text{Tc}$  by emitting gamma radiation, immediately after it is formed.
- b) It will decay by emitting an alpha particle immediately after it is formed
- c) It will decay by emitting a gamma photon some measurable time after it is formed.
- d) It will not undergo radioactive decay.
15. The decay of Tc-99m to Tc-99g is an example of:
- a) internal conversion
- b) neutrino production
- c) isomeric transition
- d) photoelectric effect
- e) none of the above.
16. After an atom has decayed by giving off a negative beta particle and a gamma ray, the remaining atom is:
- a) An atom of a new element having an atomic number one higher than the old and with no or little change in mass number.
- b) An atom of a new element having an atomic number one higher than the old and with a significant lowering of mass number.
- c) Unchanged except it has now become stable.
- d) An atom of a new element having an atomic number one less than the old and with no or little change in mass number.
17. Internal conversion is most similar diagrammatically to:
- a) isomeric transition
- b) compton effect
- c) pair production
- d) photoelectric effect

18. The formula  $E_e = E_\gamma - BE$  describes which of the following interactions with matter?

- a) Compton effect
- b) photoelectric effect
- c) pair production
- d) isomeric transition
- e) none of the above

19. Pair production takes place

- a) only in presence of nuclei
- b) only in a vacuum
- c) only in solids
- d) none of the above

20. The literature value for the  $\beta^-$  energy of  $\text{Ca}^{45}$  is 0.255 MeV. This represents

- a) the mean energy
- b) the median energy
- c) the maximum energy
- d) the root mean square energy

21. In  $\beta^-$  emission, the total decay energy is shared between the  $\beta^-$  particle and

- a) a neutron
- b) a neutrino
- c) a  $\beta^+$ -particle
- d) there is no sharing involved

22. Answer True/False to the following statements regarding  $\beta^+$  - emitters.

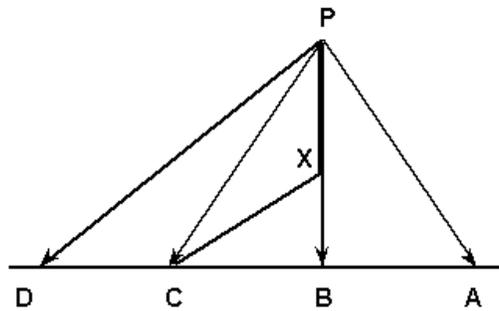
- a) Positrons are imaged following their interaction in a sodium iodide crystal
- b)  $\beta^+$  - emitting nuclides have previously undergone pair production
- c) When a  $\beta^+$  at its rest mass interacts with matter, it loses its energy by photoelectric and Compton effects
- d) The process that competes with  $\beta^+$  emission is called isomeric transition

23. In  $\alpha$ -decay which of the following takes place?

- a) The Z number of the daughter is 2 greater than of the parent
- b) The A number of the daughter is 2 greater than of the parent
- c) The Z number of the daughter is 2 less than of the parent
- d) The A number of the daughter is 2 less than of the parent
- e) c and d

24. Which of the following processes occurs spontaneously to reduce the N/P ratio?

- a)  $\beta^-$  emission
- b)  $\beta^+$  emission
- c)  $\alpha^{2+}$  emission
- d)  $\alpha^{2-}$  emission



25. Refer to the diagram above and match the mode of decay with the appropriate line in the composite decay scheme:

- |    |               |       |          |
|----|---------------|-------|----------|
| a. | $\beta$ minus | _____ | Line PA  |
| b. | $\beta$ plus  | _____ | Line PB  |
| c. | EC            | _____ | Line PXC |
| d. | IT            | _____ | Line PC  |
| e. | $\alpha$      | _____ | Line PD  |

26. Answer True/False to the following statements

- In the Compton effect,  $E_{\gamma 2}$  depends upon,  $E_{\gamma 1}$
- In the Photoelectric effect,  $E_{\gamma 2}$  depends upon  $E_{\gamma 1}$
- Pair production results in  $e^+$  and an  $e^-$  emitted at a  $180^\circ$  angle to each other
- A result of the Compton effect is pair production
- The 511 keV positrons in pair production annihilate electrons in matter

27. Which of the following is/are example(s) of specific activity?

- mg/Ci
- Ci/ $\mu$ mole
- counts/mmole
- a and c
- b and c

28. Which of the following accurately defines a millicurie?

- $3.7 \times 10^7$  counts/sec
- $3.7 \times 10^7$  counts/min
- $3.6 \times 10^7$  disintegrations/sec
- $3.7 \times 10^7$  disintegrations/sec

29. Answer True/False to the following statements

- Tc-99m decays by internal conversion to Tc-99g
- $\beta^+$  decay competes with  $\beta^-$  decay in many nuclides
- Internal conversion electrons emitted from inside an internal organ lose approximately 10% of their energy in that organ
- Tc-99g ( $t_{1/2} = 2 \times 10^5$  yr) has been discovered in Siberian mineral deposits.

30. Characteristic radiation may be produced by the interaction of \_\_\_\_\_ and matter. (Answer True/False)
- Electrons
  - Protons
  - Photons
  - Neutrons
31. For pair production interactions (Answer True/False)
- Electrons and positrons are produced.
  - The incident photons must have energies greater than or equal to 1.02 MeV.
  - The total energy of the incident photon is divided between the kinetic energy of the positron and the electron.
  - The annihilation of the positron produces 1.02 MeV photons.
  - The electron and positron are emitted in opposite directions.
32. For oxygen-15 decay (Answer True/False)
- The atomic number (Z) decreases.
  - A neutrino is emitted.
  - The mass of the daughter is less than that of the parent.
  - 0.511 MeV photons are emitted.
33. As atomic number increases, the number of neutrons in the nucleus
- decreases, but mass number increases.
  - increases the same as the atomic number.
  - increases, but mass number remains constant.
  - increases at a somewhat greater rate than the atomic number increase.
  - remains constant.
34. Radionuclides decaying by isomeric transition
- emit only gamma rays.
  - emit only characteristic x-rays.
  - emit only gamma rays and characteristic x-rays.
  - emit only positrons.
  - may emit x-rays, gamma rays, conversion electrons and Auger electrons.
35. Nuclear transitions involving only a change of energy state are:
- called "isomeric" and involve emission of photons.
  - called "isomeric" and involve emission of beta particles.
  - called "isomeric" and involve neutron emission.
  - called "isobaric" and involve electron capture.

36. Which one of the following is not a likely product of the decay of a neutron-rich species?
- gamma rays
  - beta-minus particles
  - characteristic x-rays
  - Auger electrons
  - beta-plus particles
37. Select the answer which has the following radionuclide listed in order of increasing gamma ray energy.
- Xe-133
  - I-125
  - I-131
  - Tc-99m
  - Cs-137
- 1,2,3,4,5
  - 1,2,4,3,5
  - 2,1,4,3,5
  - 2,1,4,5,3
  - 2,4,1,3,5
38. Electrons are emitted as a direct result of which of the following processes?
- Internal conversion
  - isomeric transitions
  - compton interactions
  - electron capture
  - photoelectric interactions
- 1,2,3,5
  - 1,3,5
  - 3,4,5
  - 1,3,4,5
  - 1,2,3,4,5
39. The energy equivalent of the rest mass of the electron is:
- 511 keV
  - 81 keV
  - 1.022 MeV
  - 364 keV
40. Gamma rays from Tc-99m are most likely to undergo photoelectric absorption in:
- patient
  - collimator
  - sodium iodide detector
  - Geiger Muller detector

41. Radiations emitted by a radioactive source decaying by electron capture may include:

1. Beta particles
2. Gamma rays
3. Conversion electrons
4. x-rays
5. Auger electrons

- a. 1,2,3,4
- b. 1,2,4,5
- c. 1,3,4,5
- d. 1,2,3,5
- e. 2,3,4,5

42. The FWHM energy resolution of the detector which produced the pulse height spectrum below is

- a. 6.3%
- b. 8.5%
- c. 9.5%
- d. 10.5%

