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 $^{73}_{35}$ 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 $^{238}_{92}$ U. What is
   
   _____ a) number of protons   _____ e) number of freons  
   _____ b) number of neutrons   _____ f) number of positrons  
   _____ c) number of electrons   _____ g) atomic mass  
   _____ d) number of nucleons   _____ 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) $^{131}_{53}$I, $^{131}_{54}$Xe, $^{131}_{52}$Te, $^{131}_{51}$Sb
b) $^{131}_{53}$I, $^{132}_{54}$Xe, $^{130}_{52}$Te, $^{129}_{51}$Sb
c) $^{129}_{55}$Cs, $^{129}_{54}$Xe, $^{129}_{53}$I
d) a and c

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

$$^{238}_{92}U \text{(3n,2p)} \rightarrow \_ \_ \_ \_$$

a) 92, 239
b) 90, 239
c) 92, 238
d) 90, 238

14. The $^{99m}$Tc nucleus is a metastable state of Tc. This means that

a) It will decay to $^{99g}$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 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. $\beta^{-}$ ________ Line PA
b. $\beta^{+}$ ________ Line PB
c. EC ________ Line PXC
d. IT ________ Line PC
e. $\alpha$ ________ Line PD

26. Answer True/False to the following statements

a) In the Compton effect, $E_{\gamma 2}$ depends upon, $E_{\gamma 1}$  

b) In the Photoelectric effect, $E_{\gamma 2}$ depends upon $E_{\gamma 1}$

c) Pair production results in $e^{+}$ and an $e^{-}$ emitted at a $180^\circ$ angle to each other

d) A result of the Compton effect is pair production

e) The 511 keV positrons in pair production annihilate electrons in matter

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

a) mg/Ci
b) Ci/μmole
c) counts/μmole
d) a and c
e) b and c

28. Which of the following accurately defines a millicurie?

a) $3.7 \times 10^7$ counts/sec
b) $3.7 \times 10^7$ counts/min
c) $3.6 \times 10^7$ disintegrations/sec
d) $3.7 \times 10^7$ disintegrations/sec

29. Answer True/False to the following statements

a) Tc-99m decays by internal conversion to Tc-99g
b) $\beta^{+}$ decay competes with $\beta^{-}$ decay in many nuclides

c) Internal conversion electrons emitted from inside an internal organ lose approximately 10% of their energy in that organ

d) 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)

   a) Electrons
   b) Protons
   c) Photons
   d) Neutrons

31. For pair production interactions (Answer True/False)

   a) Electrons and positrons are produced.
   b) The incident photons must have energies greater than or equal to 1.02 MeV.
   c) The total energy of the incident photon is divided between the kinetic energy of the positron and the electron.
   d) The annihilation of the positron produces 1.02 MeV photons.
   e) The electron and positron are emitted in opposite directions.

32. For oxygen-15 decay (Answer True/False)

   a) The atomic number (Z) decreases.
   b) A neutrino is emitted.
   c) The mass of the daughter is less than that of the parent.
   d) 0.511 MeV photons are emitted.

33. As atomic number increases, the number of neutrons in the nucleus

   a. decreases, but mass number increases.
   b. increases the same as the atomic number.
   c. increases, but mass number remains constant.
   d. increases at a somewhat greater rate than the atomic number increase.
   e. remains constant.

34. Radionuclides decaying by isomeric transition

   a. emit only gamma rays.
   b. emit only characteristic x-rays.
   c. emit only gamma rays and characteristic x-rays.
   d. emit only positrons.
   e. may emit x-rays, gamma rays, conversion electrons and Auger electrons.

35. Nuclear transitions involving only a change of energy state are:

   a. called "isomeric" and involve emission of photons.
   b. called "isomeric" and involve emission of beta particles.
   c. called "isomeric" and involve neutron emission.
   d. 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?
   a. gamma rays
   b. beta-minus particles
   c. characteristic x-rays
   d. Auger electrons
   e. beta-plus particles

37. Select the answer which has the following radionuclide listed in order of increasing gamma ray energy.
   1. Xe-133
   2. I-125
   3. I-131
   4. Tc-99m
   5. Cs-137
   a. 1,2,3,4,5
   b. 1,2,4,3,5
   c. 2,1,4,3,5
   d. 2,1,4,5,3
   e. 2,4,1,3,5

38. Electrons are emitted as a direct result of which of the following processes?
   1. Internal conversion
   2. isomeric transitions
   3. compton interactions
   4. electron capture
   5. photoelectric interactions
   a. 1,2,3,5
   b. 1,3,5
   c. 3,4,5
   d. 1,3,4,5
   e. 1,2,3,4,5

39. The energy equivalent of the rest mass of the electron is:
   a. 511 keV
   b. 81 keV
   c. 1.022 MeV
   d. 364 keV

40. Gamma rays from Tc-99m are most likely to undergo photoelectric absorption in:
   a. patient
   b. collimator
   c. sodium iodide detector
   d. 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%