

BioE 1330 - Review Chapters 7, 8, and 9 (Nuclear Medicine)

9/27/2018

Instructions: On the Answer Sheet, enter your 2-digit ID number (with a leading 0 if needed) in the boxes of the ID section. *Fill in the corresponding numbered circles.* Answer each of the numbered questions by filling in the corresponding circles in the numbered question section. Print your name in the space at the bottom of the answer sheet. Sign here stating that you have neither given nor received help.

your signature

1. Regarding isomers in nuclear medicine, the following is (are) true:

- I. They have the same number of protons.
- II. They have the same number of neutrons.
- III. They have different energy levels, with at least one being considered metastable.

- A. I, II, and III
- B. I
- C. I and II
- D. II and III
- E. I and III

2. Regarding different isotopes of the same element, the following are true:

- I. They have the same number of protons.
- II. They have the same atomic mass.
- III. They are chemically identical (ignoring present electron states).

- A. II and III
- B. I and II
- C. I
- D. I and III
- E. I, II, and III

3. The following are true about nuclear binding energy, *except*, (or all are true)

- A. All of the others are true.
- B. It is equivalent to electron binding energy, but for the particles within the nucleus.
- C. For protons, it accounts for the fact that they can overcome the electrostatic repulsion within the nucleus.
- D. For a given nuclide it is dictated by the difference between the sum of the masses of protons, neutrons, and electrons and an atom's actual mass (the mass defect).
- E. The average binding energy per nucleon is identical for all stable elements.

4. Regarding the line of stability for nuclides,

- I. It relates the number of neutrons to the number of protons for stable nuclides, and is actually a curve.
- II. Nuclides to the left of it tend to experience decay in which a neutron “changes” into a proton.
- III. Nuclides to the right of it tend to be positron emitters.

- A. I and III
- B. II and III
- C. I and II
- D. I, II, and III
- E. I

5. The following are true about positron emitters, *except*

- A. They include atoms found in normal organic molecules.
- B. They tend to be isotopes with too many neutrons.
- C. Their decay leads to the creation of antimatter.
- D. Their decay leads to the creation of two 511 keV gamma photons.
- E. They are particularly useful in imaging brain function.

6. *Unlike* in x-ray based imaging modalities, in nuclear medicine

- A. high energy photons are used to image.
- B. orienting the patient with the desired organ near the detector reduces total attenuation in the intervening tissue.
- C. we can increase detector efficiency by making it thicker, but this reduces resolution.
- D. tomographic slices may be reconstructed.
- E. to get more signal we can increase dose.

7. Which of the following statements is *false*?

- A. In PET imaging the attenuation factor for the pair of photons depends on the location of the activity along the line of response.
- B. PET imaging uses isotopes of elements more commonly occurring in biological systems than SPECT.
- C. Coincidence detection in PET is used to determine the direction of travel of the two simultaneously emitted gamma photons, and hence to decide on which line the radioactivity occurs.
- D. An uncertainty always exists as to the location of the positron decay due to the distance the positron travels before annihilating with an electron.
- E. None of them

8. The following are true of CT and Nuclear Medicine *except*

- A. CT relies on *emission* and Nuclear Medicine on *transmission*.
- B. CT uses x-rays and Nuclear Medicine uses gamma rays.
- C. Both image modalities use high energy photons to penetrate the patient’s tissue.
- D. CT generally images anatomy and Nuclear Medicine generally images physiological function.
- E. Both modalities involve radiation risk to the patient.

9. The following are true of Radioactive Decay *except*

- A. It is accompanied by a change in mass that is converted into energy according to $E = MC^2$
- B. Energy is released in the process, by particle motion and radiation.
- C. It is primarily a process involving the configuration of electrons in an atom.
- D. It can be viewed as the attempt of a radionuclide off the “line of stability” (on the graph of the number of neutrons vs. the number of protons) to reach the line of stability.
- E. It is driven by a change in nuclear binding energy, which holds the protons and neutrons together in a nucleus.

10. Metastable technetium, or Tc-99m, has some desirable properties for a radiotracer, including which of the following?

- I. Its decay yields beta particles which are harmless.
- II. Its decay yields high-energy photons with known energy, allowing for specific detection.
- III. It is distributed in the body in a physiologically meaningful way, yielding useful diagnostic information.

- A. III only
- B. I and III
- C. I and II
- D. II and III
- E. I, II, and III

11. Which of the following statements about PET and SPECT is (are) true?

- I. Of the two modalities, SPECT uses lighter elements more common in natural organic molecules and requires lower concentrations of these elements.
- II. Both PET and SPECT are tomographic modalities, but only SPECT has a corresponding non-tomographic modality (Planar Scintigraphy).
- III. PET requires the coincident detection of two simultaneous high-energy photons, while SPECT requires just one, but in both cases the photons are γ particles.

- A. II and III
- B. I and II
- C. I, II, and III
- D. only III
- E. I and III

12. Which of the following statements is (are) TRUE about detector crystals in Anger cameras?

- I - Thick detectors are less efficient than thin detectors, but they provide greater spatial resolution.
- II - Each gamma ray produces a scintillation consisting of many light photons.
- III - Multiple small crystals are arranged in a grid to permit determination of the location of the radiation.

- A. II and III
- B. I and III
- C. only III
- D. I and II
- E. only II

13. Which of the following statements is FALSE about PET?

- A. In PET imaging the attenuation factor for the pair of photons (pairwise attenuation) depends on the location of the activity along the *Line of Response*.
- B. PET scanners are most often sold today combined with a CT scanner, enabling accurate registration between functional and anatomical images, as well as a built-in means of calibrating for attenuation.
- C. An uncertainty always exists as to the location of the positron decay due to the distance the positron travels before annihilating with an electron.
- D. Coincidence detection in PET is used to determine the direction of travel of the two simultaneously emitted gamma photons, and hence to decide on which line the radioactivity occurs.
- E. PET is one the two major forms of Emission Computed Tomography, with SPECT being the other.

14. Regarding two atoms of the same isotope, the following is (are) true:

- I. They have the same number of protons.
- II. They have the same number of neutrons.
- III. They may have different energy levels, with at least one being considered metastable, and thereby represent different isomers.

- A. I and II
- B. I, II, and III
- C. I and III
- D. I
- E. II and III

15. The following are true about nuclear binding energy, *except*

- A. For protons, it accounts for the fact that they can overcome the electrostatic repulsion within the nucleus.
- B. For a given nuclide it is dictated by the difference between the sum of the masses of protons, neutrons, and electrons and an atom's actual mass (the mass defect).
- C. It is equivalent to electron binding energy, but for the particles within the nucleus.
- D. The average binding energy per nucleon varies with the particular nuclide, and accounts for the relative stability of atoms.
- E. Radioactive decay leads to atoms with lower average binding energy per nucleon.

16. Radionuclides are selected as radiotracers for a specific application in nuclear medicine imaging based on which of the following characteristics?

- I. Decay mode of the radionuclide.
- II. Half-life of the radionuclide.
- III. Chemical interactions of the radionuclide with organic systems.

- A. I and II.
- B. II and III.
- C. I, II, and III.
- D. I and III.
- E. only II.

17. *Unlike CT*, in nuclear medicine

- A. tomographic slices may be reconstructed by combining radiation detected along multiple linear paths.
- B. signal can be increased by increasing the radiation dose.
- C. electromagnetic radiation, not particulate radiation, is used to image.
- D. crystals are used to convert high energy photons into light photons.
- E. reducing the distance between the desired organ and the surface of the patient reduces total attenuation along the path of the photon.

18. In a sample of 1000 atoms undergoing nuclear decay, if it takes 5 seconds for 100 atoms to decay, what is the half-life of the sample?

- A. Between 30-100 seconds
- B. Between 1-3 seconds
- C. Between 10-30 seconds
- D. None of the other ranges contain the correct value
- E. Between 3-10 seconds

19. Metastable technetium, or Tc-99m, has some desirable properties for a radiotracer, including which of the following?

- I It can be produced cheaply on the hospital site for immediate use.
- II Its decay yields high-energy photons clustered around a particular energy, allowing for specific detection.
- III Its radioactivity is so low that it is undetectable within 60 seconds of its administration into a patient.

- A. II and III
- B. I, II, and III
- C. II only
- D. I and II
- E. I and III

- 20.** The spatial resolution of a gamma camera can be improved by many factors, including:
- A. Increasing the distance between the patient and the camera
 - B. Increasing the obesity of the patient
 - C. Decreasing the length of the lead septa in the collimator
 - D. None of the other choices
 - E. Decreasing the thickness of the scintillation crystal
- 21.** You have a sample of a radioactive element that has activity $A = 256$ mCi (milliCuries) at time $t = 0$ seconds. Its decay constant is $\lambda = 10^{-2}\text{s}^{-1}$. What is the minimum amount of time before the activity of your sample is less than 10 percent of its initial value?
- A. Between 30 and 100 seconds
 - B. Between 300 and 1000 seconds
 - C. More than 1000 seconds
 - D. Between 1 and 30 seconds
 - E. Between 100 and 300 seconds
- 22.** SPECT imaging relies on sequential conversions of energy from one form to another. Select the choice that lists the correct sequence of energy forms in a SPECT scan.
- A. Radiotracer - α -particle - light photon - electron stream - voltage in a computer
 - B. Radiotracer - γ -ray - light photon - electron stream - voltage in a computer
 - C. Radiotracer - α -particle - electron stream - light photon - voltage in a computer
 - D. Radiotracer - γ -ray - electron stream - light photon - voltage in a computer
 - E. None of the other choices
- 23.** What is the best advantage of PET-CT imaging?
- A. None of the other choices represent advantages
 - B. Decreases the cost of acquiring images
 - C. Merges functional and anatomic data together
 - D. Less patient time spent in the scanner
 - E. Lowers the radiation dose to the patient

24. Which of the following statements about PET and SPECT are true?

- I. PET uses the coincident detection of two simultaneous γ -rays, while SPECT uses just one γ ray.
- II. PET generally uses low atomic number atoms whereas SPECT generally uses higher atomic number atoms.
- III. PET and SPECT both use “Lines of Response” along which events are presumed to occur, without requiring collimators.

- A. II and III
- B. I and II
- C. I only
- D. I, II, and III
- E. I and III

25. All of the following occur during a PET scan, EXCEPT:

- A. Introduction of a radioactive substance into a patient
- B. Electron annihilation
- C. Application of an RF pulse
- D. Radioactive decay
- E. Unwanted attenuation of radiation

26. Consider two radionuclides P and Q. Suppose the half-life of P is twice that of Q. At $t=0$, we have N_0 atoms of each radionuclide. Given the decay constants are λ_P and λ_Q respectively, when will the radioactivities of two radionuclides be equal? (Hint: Radioactivity $A = \lambda N$)

- A. $\lambda_P/\ln 2$
- B. $\ln 2/\lambda_P$
- C. λ_P
- D. $1/\lambda_P$
- E. $2/\lambda_P$

27. Which one of the following statements is FALSE (or are they all TRUE)?

- A. Radiotracers in nuclear medicine make use of radionuclides that emit radiation of appropriate type and energy, have half-lives that are appropriate, and are chemically inert.
- B. All of them are TRUE.
- C. Nuclear medicine produces images that depict the distribution of a radiotracers; this distribution is generally governed by body function, and not simply structure.
- D. Planar scintigraphy is the nuclear medicine analog of projection radiography.
- E. Event positioning is based on a center-of-mass calculation; unlike radiographic image formation, this takes place on a photon-by-photon basis.

28. Consider an Anger camera with only one parallel collimator hole. The measured intensity is the energy deposited on the camera *per unit time per unit area*. Suppose the hole diameter is d , and a point source with radioactivity of A is at a distance of r from the camera, directly below the hole. How will the measured intensity be changed if we double the hole diameter, ignoring secondary effects such as due to collimator height?

- A. 1/2 of original intensity
- B. 1/4 of original intensity
- C. Cannot be determined from given information
- D. Same
- E. Doubles

29. Suppose a single-head system requires N counts in a 10 min scan using an all-purpose collimator. Let us imagine performing the same study with a two-head system instead, and let the two new collimators have higher resolution with just 25 percent of the sensitivity of the all-purpose collimator on the single-head system. How long will it take to achieve the same counts as the single-head system?

- A. 30 min.
- B. 15 min.
- C. 10 min.
- D. 25 min.
- E. 20 min.

30. Please match following terms with their definitions

- a - Doppler effect
- b - SPECT
- c - PET
- d - Iterative reconstruction
- e - Planar scintigraphy

1 - the nuclear medicine analog of projection radiography.

2 - has no projection analog and is based on coincidence detection of paired gamma rays following positron-electron annihilation.

3 - based on an ensemble of projection images, each of which is a conventional planar scintigram.

4 - the change in frequency of sound due to the relative motion of the source and receiver.

5 - a newer, more computer intensive approach that implicitly takes the random nature of decay into account and can incorporate models of attenuation, scatter, and blur.

- A. a - 2, b - 5, c - 1, d - 3, e - 4
- B. a - 3, b - 4, c - 2, d - 5, e - 1
- C. a - 4, b - 3, c - 5, d - 2, e - 1
- D. a - 4, b - 3, c - 2, d - 5, e - 1
- E. a - 4, b - 3, c - 2, d - 1, e - 5

31. Which of the following statements are TRUE about crystals used to detect gamma photons in Anger cameras?

- I - Thick detectors are more efficient than thin detectors, but they provide less spatial resolution.
- II - Thick detectors are less efficient than thin detectors, but they provide greater spatial resolution .
- III - Many small crystals are arranged in a grid to permit determination of the location of the radiation.
- IV - A single large crystal is used to produce scintillations that are detected by multiple photomultiplier tubes.

- A.** I and IV
- B.** None of them
- C.** II and III
- D.** II and IV
- E.** I and III

32. Which of the following statements is *false* about PET (or all are true)?

- A.** In PET imaging the attenuation factor for the combination of the two photons is independent of the location of the activity along the line of response (LOR), and therefore that factor can be measured for each LOR.
- B.** All are true
- C.** The difference in traveling times of the two coincident gamma photons is used to determine the location of the radioactivity.
- D.** An uncertainty on the order of millimeters always exists as to the location of the positron decay due to the distance the positron travels before annihilating with an electron.
- E.** Coincidence detection in PET is used to determine the direction of travel of the two simultaneously emitted gamma photons, and hence to decide on which line the radioactivity occurs.

33. Which one of the following should we consider when choosing which radionuclide to use for imaging?

- 1 - The radionuclides should be useful and safe to trace in the body.
- 2 - The radionuclides should emit gamma rays as monochromatic as possible.
- 3 - The radionuclides must be clean gamma ray emitters, which means that they do not emit alpha or beta particles.
- 4 - The radionuclides should have a half life on the order of seconds.

- A.** 1,2,4
- B.** 1,2,3
- C.** 2,3,4
- D.** All of them
- E.** None of them

34. Regarding isomers in nuclear medicine, the following is (are) true:

- I. They have different numbers of neutrons.
- II. An example that is widely used in nuclear medicine is Technetium-99 and Technetium-99m.
- III. They are the same isotope with different energy levels, with at least one being considered metastable.

- A. I and III
- B. I and II
- C. I, II, and III
- D. III
- E. II, and III

35. The following are true about positron emitters, *except*

- A. They are used in devices that nowadays typically also contain a CT scanner.
- B. Their decay leads to the generation of antimatter and subsequently to the creation of two 511 keV gamma photons moving in directions approximately 180 degrees apart.
- C. They are particularly useful in imaging physiological function.
- D. They include atoms with low atomic number typically found in normal organic molecules, such as carbon and oxygen.
- E. They are used in SPECT to create tomographic images.

36. Which of the following statements is *false*?

- A. An uncertainty always exists as to the location of the positron decay due to the distance the positron travels before annihilating with an electron.
- B. Coincidence detection in PET is used to determine the direction of travel of the two simultaneously emitted gamma photons, and hence to decide on which line of response the radioactivity occurs.
- C. None of the others is false.
- D. In PET imaging the attenuation factor for the pair of photons generated on a given line of response is independent of the location of the activity along that line of response.
- E. Random occurrences in which two different decays each contribute a photon that is detected within the same time window constitute a source of noise in PET imaging.

37. Which of the following statements is *false* about Anger cameras?

- A. Each gamma particle produces a scintillation consisting of many light photons.
- B. Gating acquisition to the electrocardiogram reduces motion artifact from cardiac motion.
- C. Lead septa are required to generate a projection image
- D. The contribution from Compton scattering to the image is reduced by analyzing the pulse height of the combined responses of the photomultiplier tubes to each detected gamma particle.
- E. Multiple photomultiplier tubes, one for each pixel in the image, are arranged in a grid behind a large crystal.

38. The spatial resolution of a gamma camera can be improved by many factors, including:

- A. Decreasing the thickness of the scintillation crystal
- B. Decreasing the length of the lead septa in the collimator
- C. Increasing the distance between the lead septa in the collimator
- D. None of the other choices
- E. Increasing the distance between the patient and the camera

39. Which of the following statements is (are) *true* about the analysis of pulse height in the detection of gamma particles by Anger cameras?

- I - It permits rejection of Compton scattering.
- II - It permits rejection of multiple simultaneous gamma photons.
- III - It is also called *Scintillation Spectrometry*.

- A. I, II, and III
- B. II and III
- C. Only II.
- D. I and III
- E. I and II

40. Which of the following is (are) *true* about SPECT and PET?

- I. Each has a corresponding projection modality.
- II. Each is a tomographic imaging modality based on the emission of gamma particles from within the patient.
- III. Each requires the use of collimators.

- A. only II.
- B. I and II.
- C. I and III.
- D. I, II, and III.
- E. II and III.

41. Which of the following is (are) *true* about *mass defect*?

- I. It is the difference between the sum of the masses of the isolated protons, neutrons, and electrons of an atom and the actual mass of the atom.
- II. It is translated via $E = mc^2$ into the binding energy holding the atom together, which may also be expressed in MeV.
- III. It is expressed in unified atomic mass units (u), where 12 u = the mass of Carbon-12

- A. I, II, and III.
- B. I and II.
- C. I and III.
- D. II and III.
- E. Only I.

42. Which of the following is (are) *true* about the “line of stability” for nuclides?

- I. On coordinates of the number of neutrons vs the number of protons, it plots the most stable isotope of each element.
- II. At low atomic numbers it shows that the atomic mass tends to be twice the atomic number.
- III. At high atomic numbers, it shows that the number of neutrons tends to be smaller than the number of protons.

- A. I and III.
- B. Only I.
- C. I, II, and III.
- D. I and II.
- E. II and III.

43. The following are true of CT and Nuclear Medicine *except*, or all are true.

- A. CT uses x-rays and Nuclear Medicine uses gamma rays, both being high energy photons whose spectra actually overlap.
- B. Both modalities involve radiation risk to the patient.
- C. CT generally images anatomy with relatively high resolution and Nuclear Medicine generally images physiological function with relatively low resolution.
- D. CT relies on *transmission* through the body and Nuclear Medicine on *emission* from within the body.
- E. All are true.

44. Metastable technetium, or Tc-99m, has some desirable properties for a radiotracer, including which of the following?

- I. It can be produced cheaply on the hospital site for immediate use.
- II. Its decay yields high-energy photons clustered around a particular energy, allowing for specific detection.
- III. Its half life is long enough to last through a study but short enough so that the patient can be discharged in a reasonable time

- A. II and III
- B. I, II, and III
- C. II only
- D. I and II
- E. I and III

45. *Unlike* in nuclear medicine, in X-ray based imaging modalities,

- A. signal can be increased by increasing the radiation dose.
- B. one or more crystals are used to convert high energy photons into light photons.
- C. attenuation by tissue is the desired imaging parameter.
- D. electromagnetic radiation, not particulate radiation, is used to image.
- E. tomographic slices may be reconstructed by combining radiation detected along multiple linear paths.

46. Which of the following statements is *false* about Anger cameras?

- A. Lead septa are required to generate a projection image
- B. The contribution from Compton scattering to the image is reduced by analyzing the pulse height of the combined responses of the photomultiplier tubes to each detected gamma particle.
- C. Each gamma particle produces a scintillation consisting of many light photons.
- D. Multiple photomultiplier tubes are arranged in a grid behind a large crystal that act in concert to determine the location of the incoming photons with a spatial resolution greater than that of the tubes.
- E. Average rates, rather than individual counts, of the gamma photons are all that are measured.

47. Which of the following is (are) *true* about the “line of stability” for nuclides?

- I. Spontaneous nuclear decay tends to move towards it.
 - II. Positron emitters are on one side of it, while beta emitters are on the other.
 - III. At higher atomic number, it shows that the number of neutrons tends to be larger than the number of protons.
- A. I and III.
 - B. I, II, and III.
 - C. II and III.
 - D. I and II.
 - E. Only I.

48. Which of the following statements about combined PET/CT scanners is *false* (or all are true)?

- A. The CT scanner is used to determine the attenuation along each Line of Response in the PET scanner.
- B. Virtually every PET scanner sold today also contains a CT scanner.
- C. Registration of the two imaging modalities is greatly facilitated since the patient only needs to be slid a short distance between the actual scanners.
- D. All are true.
- E. The primarily anatomical, lower-resolution information from the CT scanner is combined with the primarily physiological, higher-resolution information from the PET scanner.

49. Metastable technetium, or Tc-99m, has some desirable properties for a radiotracer, including which of the following?

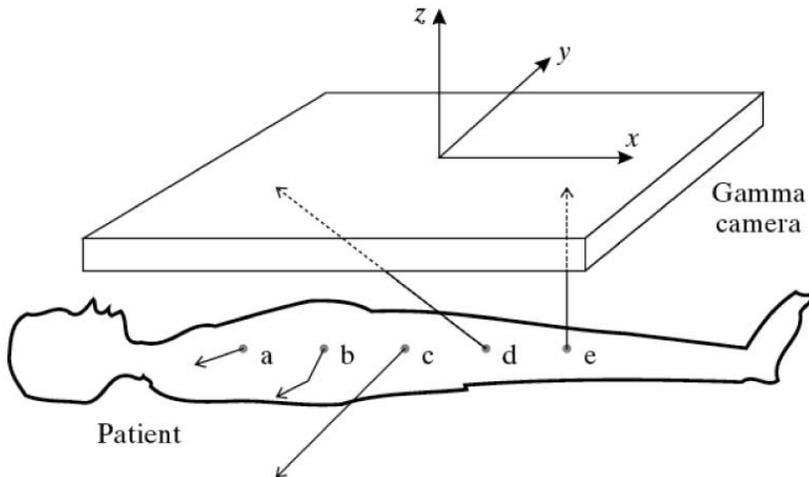
- I. It can be produced cheaply on the hospital site for immediate use.
 - II. Its decay yields high-energy electrons, known as “beta” particles.
 - III. Its half life is long enough to last through a study but short enough so that the patient can be discharged in a reasonable time
- A. I and II
 - B. I and III
 - C. I, II, and III
 - D. II only
 - E. II and III

- 50.** Which of the following statements about combined PET/CT scanners is *false* (or all are true)?
- A.** Registration of the two imaging modalities is greatly facilitated since the patient only needs to be slid a short distance between the actual scanners.
 - B.** All are true.
 - C.** The primarily physiological, higher-resolution information from the CT scanner is combined with the primarily anatomical, lower-resolution information from the PET scanner.
 - D.** The CT scanner is used to determine the attenuation along each Line of Response in the PET scanner.
 - E.** Virtually every PET scanner sold today also contains a CT scanner.
- 51.** Which of the following statements is *false* about Anger cameras?
- A.** Each gamma particle produces a scintillation consisting of many light photons.
 - B.** The contribution from Compton scattering to the image is reduced by analyzing the pulse height of the combined responses of the photomultiplier tubes to each detected gamma particle.
 - C.** Lead septa are not required to generate a projection image.
 - D.** Multiple photomultiplier tubes are arranged in a grid behind a large crystal that act in concert to determine the location of the incoming photons with a spatial resolution greater than that of the tubes.
 - E.** Individual gamma photons are counted and located.
- 52.** The following are true about positron emitters, *except*, or all are true
- A.** They include atoms with low atomic number typically found in normal organic molecules, such as carbon and oxygen.
 - B.** All are true.
 - C.** They are unstable because they have too few neutrons.
 - D.** They are used in devices that nowadays typically also contain a CT scanner.
 - E.** Their decay leads to the generation of antimatter and subsequently to the creation of two 511 keV gamma photons moving in directions approximately 180 degrees apart.
- 53.** Which of the following statements is *false* about radioactive decay (or all are true)?
- A.** All are true.
 - B.** Half-life is fifty percent of the time it takes for all of the sample to decay.
 - C.** The number of radioactive atoms remaining in a given sample decreases with time as an inverse exponential.
 - D.** Its statistics is governed by the Poisson distribution.
 - E.** The radioactivity (how many radioactive atoms are undergoing decay every second) in a given sample decreases with time as an inverse exponential.

54. Which of the following statements is *false* about photomultiplier tubes (or all are true)?

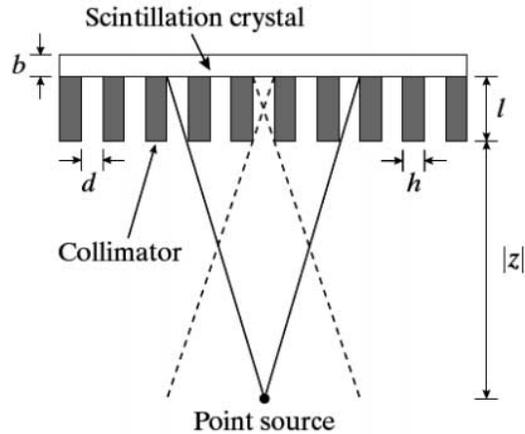
- A. Uses a series of dynodes at successively more positive voltage within the tube to create increasing numbers of cascading electrons from an initial few electrons.
- B. All are true.
- C. Uses a photocathode to generate electrons from incoming photons.
- D. Is designed to be extremely sensitive to light photons.
- E. Used in an Anger camera to produce an electrical signal whose pulse height is related to the number of light photons generated by a gamma event.

55. In the following diagram on an Anger camera in action, which of the gamma photons will *increase* the signal to noise ratio? (Note: the lower case letters in the diagram do *not* correspond to the upper case letters for the answers!).



- A. 'd' in the diagram.
- B. 'a' in the diagram.
- C. 'b' in the diagram.
- D. 'e' in the diagram.
- E. 'c' in the diagram.

56. The collimator geometry configuration of Anger camera is shown in the image below. The collimator resolution is given by $R_C = \frac{d}{l}(l + b + |z|)$ and the sensitivity of collimator is given by $\epsilon = \left(\frac{Kd^2}{l_e(d+h)}\right)^2$, where d is the collimator hole diameter, l is the collimator hole length, b is the scintillator depth and h is the collimator length. Which of the following is *true* (or all are incorrect)?



- A. Sensitivity decreases with greater $|z|$
- B. Collimator resolution degrades as $|z|$ decreases.
- C. The collimator can actually increase the number of gamma photons hitting the scintillation crystal.
- D. There is a trade-off between resolution and sensitivity.
- E. All are incorrect.

57. The following descriptions about the instrumentation of SPECT and PET are all incorrect, *except*

- A. Both PET and SPECT require a collimator to allow only the specific photons traveling in an appropriate direction.
- B. The number of electrons at the output of a photomultiplier tube is the same as the number of light photons at the input.
- C. Thicker crystals detect more radiation than thinner crystals, and they have better resolution.
- D. The accurate position (X, Y) of the event is equal to the location of photomultiplier tube having the largest amplitude.
- E. The advantage of dynamic frame mode acquisition is that it applies the temporal succession of frame mode images and needs less storage space compared with static frame mode acquisition.

58. Which of the following is *false* about scintillations (or all of the others are true)?

- A. They are generally the first step within a detector in using high-energy photons (X-ray or gamma) to create an image.
- B. It occurs within the body providing a natural amplification of the number of useful high-energy photons reaching the detector.
- C. Like fluorescence, lower energy photons are created from higher energy photons.
- D. Unlike fluorescence, the higher energy photon causes ionization and many lower energy photons are formed from a single higher energy photon.
- E. All of the others are true.

59. Which of the following statements is *false* about this matrix (or all are true):

$$\begin{bmatrix} 1 & 0 & 2 \\ 0 & 1 & 3 \\ 0 & 0 & 1 \end{bmatrix}$$

- A. All are true.
- B. It operates in homogeneous coordinates.
- C. It performs pure translation (no rotation or scaling).
- D. It transforms coordinates for 2-dimensional locations.
- E. It performs a geometric (rigid body) transformation.

60. Which of the following statements is *false* about photomultiplier tubes (or all are true)?

- A. Used in an Anger camera to produce an electrical signal whose pulse height is related to the number of light photons generated by a gamma event.
- B. Uses a photocathode to generate electrons from incoming photons.
- C. Is designed to be extremely sensitive to high energy photons, including gamma and x-ray photons.
- D. Uses a series of dynodes at successively more positive voltage within the tube to create increasing numbers of cascading electrons from an initial few electrons.
- E. All are true.

61. Which of the following statements is (are) *true* about the analysis of pulse height in the detection of gamma particles by Anger cameras?

I - It permits rejection of Compton scattering.

II - It permits rejection of multiple simultaneous gamma photons.

III - It reports the total number of light photons hitting a single photomultiplier tube.

- A. I, II, and III
- B. II and III
- C. Only I.
- D. I and II
- E. I and III

62. Which of the following is (are) *true* about both SPECT and PET?

I. Each has a corresponding projection modality.

II. Each is a tomographic imaging modality based on the emission of gamma particles from within the patient.

III. Each involves the annihilation of matter and antimatter

- A. only II.
- B. I and II.
- C. II and III.
- D. I, II, and III.
- E. I and III.

63. *Unlike* CT, in nuclear medicine

- A. causing cancer is not a risk.
- B. crystals are used to convert high energy photons into light photons.
- C. electromagnetic radiation, not particulate radiation, is used to image.
- D. signal can be increased by increasing the radiation dose.
- E. Bremsstrahlung is not used to produce high-energy photons.

64. The following modes of decay are used in Nuclear Medicine imaging *except*, or all are used.

- A. Positron decay.
- B. Beta decay.
- C. Isomeric transition.
- D. Alpha decay.
- E. All are used.

65. Regarding single photon emitters, which of the following statements about the equation below is *false* (or all are true)?

$$\phi(x, y) = \int_{-\infty}^0 \frac{A(x, y, z)}{4\pi z^2} \exp \left\{ - \int_z^0 \mu(x, y, z'; E) dz' \right\} dz$$

- A. The contribution from each location falls off as the square of the distance, and is attenuated by the material along the line between that location and the detector.
- B. It assumes a heterogeneous tissue in terms of attenuation, and a perfect collimator.
- C. $A(x, y, z)$ is the attenuation at location (x, y, z) .
- D. All are true.
- E. It assumes mono-energetic photons, which is a good assumption assuming a given nuclear decay.

66. Regarding PET, which of the following statements about the equation below is *false* (or all are true)?

$$N_c(s_0) = N_0 \exp \left\{ - \int_{-R}^R \mu(x(s'), y(s'); E) ds' \right\}$$

- A. All are true.
- B. The effect of attenuation along a given line of response on the number of coincident detections is independent of where the positron decay occurs along the line of response.
- C. It assumes a heterogeneous tissue in terms of attenuation.
- D. It assumes no random coincidences at the 2 detectors from different positron decays.
- E. It assumes mono-energetic photons, which is a good assumption with positron decay.

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1. Regarding isomers in nuclear medicine, the following is (are) true:

- I. They have the same number of protons.
- II. They have the same number of neutrons.
- III. They have different energy levels, with at least one being considered metastable.

- A. I, II, and III
- B. I and III
- C. II and III
- D. I and II
- E. I

Explanation: The classic example is Technetium-99 and Technetium-99m
[*imaging0047.mcq*]

2. Regarding different isotopes of the same element, the following are true:

- I. They have the same number of protons.
- II. They have the same atomic mass.
- III. They are chemically identical (ignoring present electron states).

- A. I and III
- B. I, II, and III
- C. II and III
- D. I and II
- E. I

Explanation: They differ only in numbers of neutrons, which makes their atomic mass differ but not their chemical behavior.
[*imaging0048.mcq*]

3. The following are true about nuclear binding energy, *except*, (or all are true)

- A. The average binding energy per nucleon is identical for all stable elements.
- B. It is equivalent to electron binding energy, but for the particles within the nucleus.
- C. For a given nuclide it is dictated by the difference between the sum of the masses of protons, neutrons, and electrons and an atom's actual mass (the mass defect).
- D. For protons, it accounts for the fact that they can overcome the electrostatic repulsion within the nucleus.
- E. All of the others are true.

Explanation: The average binding energy per nucleon varies and accounts for the relative stability of atoms.
[*imaging0049.mcq*]

4. Regarding the line of stability for nuclides,

- I. It relates the number of neutrons to the number of protons for stable nuclides, and is actually a curve.
- II. Nuclides to the left of it tend to experience decay in which a neutron “changes” into a proton.
- III. Nuclides to the right of it tend to be positron emitters.

- A. I, II, and III
- B. I and III
- C. II and III
- D. I and II
- E. I

Explanation: All are true, see text.

[*imaging0050.mcq*]

5. The following are true about positron emitters, *except*

- A. They tend to be isotopes with too many neutrons.
- B. They include atoms found in normal organic molecules.
- C. Their decay leads to the creation of two 511 keV gamma photons.
- D. Their decay leads to the creation of antimatter.
- E. They are particularly useful in imaging brain function.

Explanation: They have too few neutrons, and so “want” to turn a proton into a neutron but giving off a positron.

[*imaging0051.mcq*]

6. *Unlike* in x-ray based imaging modalities, in nuclear medicine

- A. orienting the patient with the desired organ near the detector reduces total attenuation in the intervening tissue.
- B. to get more signal we can increase dose.
- C. we can increase detector efficiency by making it thicker, but this reduces resolution.
- D. high energy photons are used to image.
- E. tomographic slices may be reconstructed.

Explanation: Since the gamma photons in nuclear medicine originate within the body, the amount of attenuation depends on the distance between the organ and the detector.

[*imaging0052.mcq*]

7. Which of the following statements is *false*?

- A. In PET imaging the attenuation factor for the pair of photons depends on the location of the activity along the line of response.
- B. Coincidence detection in PET is used to determine the direction of travel of the two simultaneously emitted gamma photons, and hence to decide on which line the radioactivity occurs.
- C. PET imaging uses isotopes of elements more commonly occurring in biological systems than SPECT.
- D. An uncertainty always exists as to the location of the positron decay due to the distance the positron travels before annihilating with an electron.
- E. None of them

Explanation: In PET imaging the attenuation factor does not depend on the location of the activity along the line of response, because the total path traveled by both gamma particles remains the same along a given line of response for any starting point.

[*imaging0057.mcq*]

8. The following are true of CT and Nuclear Medicine *except*

- A. CT relies on *emission* and Nuclear Medicine on *transmission*.
- B. Both image modalities use high energy photons to penetrate the patient's tissue.
- C. CT uses x-rays and Nuclear Medicine uses gamma rays.
- D. CT generally images anatomy and Nuclear Medicine generally images physiological function.
- E. Both modalities involve radiation risk to the patient.

Explanation: CT relies on *transmission* and Nuclear Medicine on *emission*.

[*imaging0095.mcq*]

9. The following are true of Radioactive Decay *except*

- A. It is primarily a process involving the configuration of electrons in an atom.
- B. It is driven by a change in nuclear binding energy, which holds the protons and neutrons together in a nucleus.
- C. It is accompanied by a change in mass that is converted into energy according to $E = MC^2$
- D. Energy is released in the process, by particle motion and radiation.
- E. It can be viewed as the attempt of a radionuclide off the "line of stability" (on the graph of the number of neutrons vs. the number of protons) to reach the line of stability.

Explanation: Radioactive Decay involves the configuration of the nucleus rather than that of the electrons.

[*imaging0097.mcq*]

10. Metastable technetium, or Tc-99m, has some desirable properties for a radiotracer, including which of the following?

- I. Its decay yields beta particles which are harmless.
- II. Its decay yields high-energy photons with known energy, allowing for specific detection.
- III. It is distributed in the body in a physiologically meaningful way, yielding useful diagnostic information.

- A. II and III
- B. I, II, and III
- C. I and II
- D. I and III
- E. III only

Explanation: Tc-99m exhibits isomeric transition, which does not involve emission of a beta particle. Beta is too destructive for medical imaging. The other statements are true.

[*imaging0118.mcq*]

11. Which of the following statements about PET and SPECT is (are) true?

- I. Of the two modalities, SPECT uses lighter elements more common in natural organic molecules and requires lower concentrations of these elements.
- II. Both PET and SPECT are tomographic modalities, but only SPECT has a corresponding non-tomographic modality (Planar Scintigraphy).
- III. PET requires the coincident detection of two simultaneous high-energy photons, while SPECT requires just one, but in both cases the photons are γ particles.

- A. II and III
- B. I and II
- C. only III
- D. I and III
- E. I, II, and III

Explanation: PET uses lighter elements, more commonly occurring in natural organic molecules, and requires lower concentrations of these elements, so I is incorrect.

[*imaging0120.mcq*]

12. Which of the following statements is (are) TRUE about detector crystals in Anger cameras?

- I - Thick detectors are less efficient than thin detectors, but they provide greater spatial resolution.
- II - Each gamma ray produces a scintillation consisting of many light photons.
- III - Multiple small crystals are arranged in a grid to permit determination of the location of the radiation.

- A. only II
- B. I and II
- C. II and III
- D. I and III
- E. only III

Explanation: Thick detectors are *more* efficient than thin detectors, and they provide *less* spatial resolution, so I is false. Anger cameras use one or two large crystal detectors, so III is false.

[*imaging0121.mcq*]

13. Which of the following statements is FALSE about PET?

- A. In PET imaging the attenuation factor for the pair of photons (pairwise attenuation) depends on the location of the activity along the *Line of Response*.
- B. Coincidence detection in PET is used to determine the direction of travel of the two simultaneously emitted gamma photons, and hence to decide on which line the radioactivity occurs.
- C. PET scanners are most often sold today combined with a CT scanner, enabling accurate registration between functional and anatomical images, as well as a built-in means of calibrating for attenuation.
- D. An uncertainty always exists as to the location of the positron decay due to the distance the positron travels before annihilating with an electron.
- E. PET is one the two major forms of Emission Computed Tomography, with SPECT being the other.

Explanation: In PET imaging the attenuation factor does not depend on the location of the activity along the imaging line, because the total path traveled by both gamma particles remains the same along a given imaging line.

[*imaging0122.mcq*]

14. Regarding two atoms of the same isotope, the following is (are) true:

- I. They have the same number of protons.
- II. They have the same number of neutrons.
- III. They may have different energy levels, with at least one being considered metastable, and thereby represent different isomers.

- A. I, II, and III
- B. I and III
- C. II and III
- D. I and II
- E. I

Explanation: The classic example is Technetium-99 and Technetium-99m, which are different isomers of the same isotope.

[*imaging0126.mcq*]

15. The following are true about nuclear binding energy, *except*

- A. Radioactive decay leads to atoms with lower average binding energy per nucleon.
- B. It is equivalent to electron binding energy, but for the particles within the nucleus.
- C. For a given nuclide it is dictated by the difference between the sum of the masses of protons, neutrons, and electrons and an atom's actual mass (the mass defect).
- D. For protons, it accounts for the fact that they can overcome the electrostatic repulsion within the nucleus.
- E. The average binding energy per nucleon varies with the particular nuclide, and accounts for the relative stability of atoms.

Explanation: Radioactive decay leads to atoms with *greater* binding energy.

[*imaging0127.mcq*]

16. Radionuclides are selected as radiotracers for a specific application in nuclear medicine imaging based on which of the following characteristics?

- I. Decay mode of the radionuclide.
- II. Half-life of the radionuclide.
- III. Chemical interactions of the radionuclide with organic systems.

- A. I, II, and III.
- B. I and II.
- C. I and III.
- D. II and III.
- E. only II.

Explanation: Decay mode is important because particulate radiation is generally too dangerous (beta and alpha) for imaging. Half-life is generally from minutes to hours. Chemical interaction determines where the tracer goes.

[*imaging0132.mcq*]

17. *Unlike* CT, in nuclear medicine

- A. reducing the distance between the desired organ and the surface of the patient reduces total attenuation along the path of the photon.
- B. signal can be increased by increasing the radiation dose.
- C. crystals are used to convert high energy photons into light photons.
- D. electromagnetic radiation, not particulate radiation, is used to image.
- E. tomographic slices may be reconstructed by combining radiation detected along multiple linear paths.

Explanation: Since the gamma photons in nuclear medicine originate within the body, the amount of attenuation depends on the distance between the organ and the surface of the body. In CT, the path is all the way through the body, so total attenuation is the same no matter where the target organ is along a given path.

[*imaging0133.mcq*]

18. In a sample of 1000 atoms undergoing nuclear decay, if it takes 5 seconds for 100 atoms to decay, what is the half-life of the sample?

- A. Between 30-100 seconds
- B. Between 10-30 seconds
- C. Between 1-3 seconds
- D. Between 3-10 seconds
- E. None of the other ranges contain the correct value

Explanation: Using $N(t) = N_0 \exp(-\lambda t)$, we can solve for λ , the decay constant. The half-life is related to the decay constant by $T_{0.5} = \frac{\ln 2}{\lambda}$, which is about 33 seconds.

[*imaging0174.mcq*]

19. Metastable technetium, or Tc-99m, has some desirable properties for a radiotracer, including which of the following?

- I It can be produced cheaply on the hospital site for immediate use.
- II Its decay yields high-energy photons clustered around a particular energy, allowing for specific detection.
- III Its radioactivity is so low that it is undetectable within 60 seconds of its administration into a patient.

- A. I and II
- B. I, II, and III
- C. I and III
- D. II and III
- E. II only

Explanation: The half life of Tc-99m is about 6 hours, so it can be detected several days after the dose is given. The other statements are true.

[*imaging0175.mcq*]

20. The spatial resolution of a gamma camera can be improved by many factors, including:

- A. Decreasing the thickness of the scintillation crystal
- B. Increasing the distance between the patient and the camera
- C. Decreasing the length of the lead septa in the collimator
- D. Increasing the obesity of the patient
- E. None of the other choices

Explanation: Thinner crystals produce a narrower PSF from the scintillations, although by sacrificing efficiency of capturing the gamma photon. The other options would actually decrease the spatial resolution of the camera.

[*imaging0176.mcq*]

21. You have a sample of a radioactive element that has activity $A = 256$ mCi (milliCuries) at time $t = 0$ seconds. Its decay constant is $\lambda = 10^{-2}\text{s}^{-1}$. What is the minimum amount of time before the activity of your sample is less than 10 percent of its initial value?

- A. Between 100 and 300 seconds
- B. Between 1 and 30 seconds
- C. Between 30 and 100 seconds
- D. Between 300 and 1000 seconds
- E. More than 1000 seconds

Explanation: The radioactive decay law states that $A_t = A_0 \exp(-\lambda t)$. Solving for t , we have $t = \frac{1}{\lambda} \ln\left(\frac{A_0}{A_t}\right) = 230$ seconds.

[*imaging0177.mcq*]

22. SPECT imaging relies on sequential conversions of energy from one form to another. Select the choice that lists the correct sequence of energy forms in a SPECT scan.

- A. Radiotracer - γ -ray - light photon - electron stream - voltage in a computer
- B. Radiotracer - α -particle - light photon - electron stream - voltage in a computer
- C. Radiotracer - γ -ray - electron stream - light photon - voltage in a computer
- D. Radiotracer - α -particle - electron stream - light photon - voltage in a computer
- E. None of the other choices

Explanation: Radioactive elements decay producing γ -rays, which are converted into light photons by the scintillation crystal of the camera. This light signal is converted into an electron beam by the photomultiplier tubes, which is then decoded by the logic network, analyzed for pulse height (to reduce the effect of scatter), before being stored in the a computer. Radioactive decay producing α -particles is not used in imaging because they are too destructive.

[*imaging0178.mcq*]

23. What is the best advantage of PET-CT imaging?

- A. Merges functional and anatomic data together
- B. Lowers the radiation dose to the patient
- C. Decreases the cost of acquiring images
- D. Less patient time spent in the scanner
- E. None of the other choices represent advantages

Explanation: The merger of structural and functional information is the greatest benefit of PET-CT imaging.

[*imaging0180.mcq*]

24. Which of the following statements about PET and SPECT are true?

- I. PET uses the coincident detection of two simultaneous γ -rays, while SPECT uses just one γ ray.
- II. PET generally uses low atomic number atoms whereas SPECT generally uses higher atomic number atoms.
- III. PET and SPECT both use “Lines of Response” along which events are presumed to occur, without requiring collimators.

- A. I and II
- B. I, II, and III
- C. I only
- D. II and III
- E. I and III

Explanation: III is only true for PET. SPECT requires collimators to establish a projection.

[*imaging0181.mcq*]

25. All of the following occur during a PET scan, EXCEPT:

- A. Application of an RF pulse
- B. Radioactive decay
- C. Electron annihilation
- D. Unwanted attenuation of radiation
- E. Introduction of a radioactive substance into a patient

Explanation: RF pulses are used in MRI, not PET.

[*imaging0190.mcq*]

26. Consider two radionuclides P and Q. Suppose the half-life of P is twice that of Q. At $t=0$, we have N_0 atoms of each radionuclide. Given the decay constants are λ_P and λ_Q respectively, when will the radioactivities of two radionuclides be equal? (Hint: Radioactivity $A = \lambda N$)

- A. $\ln 2 / \lambda_P$
- B. $2 / \lambda_P$
- C. $1 / \lambda_P$
- D. $\lambda_P / \ln 2$
- E. λ_P

Explanation: For solution look at Example 7.2. Answer is $\ln 2 / \lambda_P$.

[*imaging0207.mcq*]

27. Which one of the following statements is FALSE (or are they all TRUE)?

- A. All of them are TRUE.
- B. Nuclear medicine produces images that depict the distribution of a radiotracers; this distribution is generally governed by body function, and not simply structure.
- C. Radiotracers in nuclear medicine make use of radionuclides that emit radiation of appropriate type and energy, have half-lives that are appropriate, and are chemically inert.
- D. Planar scintigraphy is the nuclear medicine analog of projection radiography.
- E. Event positioning is based on a center-of-mass calculation; unlike radiographic image formation, this takes place on a photon-by-photon basis.

Explanation: All of them are TRUE.

[*imaging0208.mcq*]

28. Consider an Anger camera with only one parallel collimator hole. The measured intensity is the energy deposited on the camera *per unit time per unit area*. Suppose the hole diameter is d , and a point source with radioactivity of A is at a distance of r from the camera, directly below the hole. How will the measured intensity be changed if we double the hole diameter, ignoring secondary effects such as due to collimator height?

- A. Same
- B. Doubles
- C. 1/4 of original intensity
- D. 1/2 of original intensity
- E. Cannot be determined from given information

Explanation: Hole size does not matter, since *per unit area* is already figured into intensity. Therefore, the intensity is the same.

[*imaging0209.mcq*]

29. Suppose a single-head system requires N counts in a 10 min scan using an all-purpose collimator. Let us imagine performing the same study with a two-head system instead, and let the two new collimators have higher resolution with just 25 percent of the sensitivity of the all-purpose collimator on the single-head system. How long will it take to achieve the same counts as the single-head system?

- A. 20 min.
- B. 10 min.
- C. 30 min.
- D. 15 min.
- E. 25 min.

Explanation: Two heads doubles the sensitivity, but the new collimator only has 1/4 the sensitivity, so the total sensitivity for the new system is half the old one. Thus it will take twice as long to accumulate the same number of counts.

[*imaging0210.mcq*]

30. Please match following terms with their definitions

- a - Doppler effect
- b - SPECT
- c - PET
- d - Iterative reconstruction
- e - Planar scintigraphy

1 - the nuclear medicine analog of projection radiography.

2 - has no projection analog and is based on coincidence detection of paired gamma rays following positron-electron annihilation.

3 - based on an ensemble of projection images, each of which is a conventional planar scintigram.

4 - the change in frequency of sound due to the relative motion of the source and receiver.

5 - a newer, more computer intensive approach that implicitly takes the random nature of decay into account and can incorporate models of attenuation, scatter, and blur.

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

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

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

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

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

Explanation: See definitions in book

[*imaging0212.mcq*]

31. Which of the following statements are TRUE about crystals used to detect gamma photons in Anger cameras?

I - Thick detectors are more efficient than thin detectors, but they provide less spatial resolution.

II - Thick detectors are less efficient than thin detectors, but they provide greater spatial resolution .

III - Many small crystals are arranged in a grid to permit determination of the location of the radiation.

IV - A single large crystal is used to produce scintillations that are detected by multiple photomultiplier tubes.

A. I and IV

B. II and III

C. I and III

D. II and IV

E. None of them

Explanation: I and II are mutually exclusive. So are III and IV.

[*imaging0213.mcq*]

32. Which of the following statements is *false* about PET (or all are true)?

- A.** The difference in traveling times of the two coincident gamma photons is used to determine the location of the radioactivity.
- B.** Coincidence detection in PET is used to determine the direction of travel of the two simultaneously emitted gamma photons, and hence to decide on which line the radioactivity occurs.
- C.** In PET imaging the attenuation factor for the combination of the two photons is independent of the location of the activity along the line of response (LOR), and therefore that factor can be measured for each LOR.
- D.** An uncertainty on the order of millimeters always exists as to the location of the positron decay due to the distance the positron travels before annihilating with an electron.
- E.** All are true

Explanation: The traveling times may indeed be different (if the radioactivity is not exactly in the middle between the detectors) but the difference is slight and not used in computing location along the LOR.

[*imaging0214.mcq*]

33. Which one of the following should we consider when choosing which radionuclide to use for imaging?

- 1 - The radionuclides should be useful and safe to trace in the body.
- 2 - The radionuclides should emit gamma rays as monochromatic as possible.
- 3 - The radionuclides must be clean gamma ray emitters, which means that they do not emit alpha or beta particles.
- 4 - The radionuclides should have a half life on the order of seconds.

- A.** 1,2,3
- B.** All of them
- C.** 1,2,4
- D.** 2,3,4
- E.** None of them

Explanation: Answer is 1, 2 and 3. Seconds to minutes is too short to be useful.

[*imaging0215.mcq*]

34. Regarding isomers in nuclear medicine, the following is (are) true:

- I. They have different numbers of neutrons.
- II. An example that is widely used in nuclear medicine is Technetium-99 and Technetium-99m.
- III. They are the same isotope with different energy levels, with at least one being considered metastable.

- A.** II, and III
- B.** I and III
- C.** I and II
- D.** III
- E.** I, II, and III

Explanation: The classic example is Technetium-99 and Technetium-99m, with the same numbers of neutrons and protons (isotope) but different energy levels due to nuclear configuration

[*imaging0261.mcq*]

35. The following are true about positron emitters, *except*

- A. They are used in SPECT to create tomographic images.
- B. They include atoms with low atomic number typically found in normal organic molecules, such as carbon and oxygen.
- C. Their decay leads to the generation of antimatter and subsequently to the creation of two 511 keV gamma photons moving in directions approximately 180 degrees apart.
- D. They are used in devices that nowadays typically also contain a CT scanner.
- E. They are particularly useful in imaging physiological function.

Explanation: SPECT is used to image “single photon emission” isotopes, typically heavy atoms such as technetium or iodine, not positron emitters.

[*imaging0262.mcq*]

36. Which of the following statements is *false*?

- A. None of the others is false.
- B. Coincidence detection in PET is used to determine the direction of travel of the two simultaneously emitted gamma photons, and hence to decide on which line of response the radioactivity occurs.
- C. In PET imaging the attenuation factor for the pair of photons generated on a given line of response is independent of the location of the activity along that line of response.
- D. An uncertainty always exists as to the location of the positron decay due to the distance the positron travels before annihilating with an electron.
- E. Random occurrences in which two different decays each contribute a photon that is detected within the same time window constitute a source of noise in PET imaging.

Explanation: They’re all true.

[*imaging0263.mcq*]

37. Which of the following statements is *false* about Anger cameras?

- A. Multiple photomultiplier tubes, one for each pixel in the image, are arranged in a grid behind a large crystal.
- B. Lead septa are required to generate a projection image
- C. Each gamma particle produces a scintillation consisting of many light photons.
- D. The contribution from Compton scattering to the image is reduced by analyzing the pulse height of the combined responses of the photomultiplier tubes to each detected gamma particle.
- E. Gating acquisition to the electrocardiogram reduces motion artifact from cardiac motion.

Explanation: Multiple photomultiplier tubes are indeed used, but not one for each pixel. Rather, they act in concert to determine the actual location of the gamma particle with a spatial resolution greater than that of the tubes.

[*imaging0264.mcq*]

38. The spatial resolution of a gamma camera can be improved by many factors, including:

- A. Decreasing the thickness of the scintillation crystal
- B. Increasing the distance between the patient and the camera
- C. Decreasing the length of the lead septa in the collimator
- D. Increasing the distance between the lead septa in the collimator
- E. None of the other choices

Explanation: Decreasing the thickness of the crystal improves resolution, though it also decreases the efficiency of detection. The other options would actually decrease the spatial resolution of the camera.

[*imaging0265.mcq*]

39. Which of the following statements is (are) *true* about the analysis of pulse height in the detection of gamma particles by Anger cameras?

- I - It permits rejection of Compton scattering.
- II - It permits rejection of multiple simultaneous gamma photons.
- III - It is also called *Scintillation Spectrometry*.

- A. I, II, and III
- B. II and III
- C. I and III
- D. I and II
- E. Only II.

Explanation: All are true.

[*imaging0266.mcq*]

40. Which of the following is (are) *true* about SPECT and PET?

- I. Each has a corresponding projection modality.
- II. Each is a tomographic imaging modality based on the emission of gamma particles from within the patient.
- III. Each requires the use of collimators.

- A. only II.
- B. I and II.
- C. I and III.
- D. II and III.
- E. I, II, and III.

Explanation: PET is not based on a projection modality, though SPECT is. PET does not require the use of collimators, though SPECT does.

[*imaging0267.mcq*]

41. Which of the following is (are) *true* about *mass defect*?

- I. It is the difference between the sum of the masses of the isolated protons, neutrons, and electrons of an atom and the actual mass of the atom.
- II. It is translated via $E = mc^2$ into the binding energy holding the atom together, which may also be expressed in MeV.
- III. It is expressed in unified atomic mass units (u), where 12 u = the mass of Carbon-12

- A. I, II, and III.
- B. I and II.
- C. I and III.
- D. II and III.
- E. Only I.

Explanation: All are true.

[*imaging0268.mcq*]

42. Which of the following is (are) *true* about the “line of stability” for nuclides?

- I. On coordinates of the number of neutrons vs the number of protons, it plots the most stable isotope of each element.
- II. At low atomic numbers it shows that the atomic mass tends to be twice the atomic number.
- III. At high atomic numbers, it shows that the number of neutrons tends to be smaller than the number of protons.

- A. I and II.
- B. I, II, and III.
- C. I and III.
- D. II and III.
- E. Only I.

Explanation: At high atomic numbers the number of neutrons tends to be *larger* than the number of protons.

[*imaging0269.mcq*]

43. The following are true of CT and Nuclear Medicine *except*, or all are true.

- A. All are true.
- B. CT relies on *transmission* through the body and Nuclear Medicine on *emission* from within the body.
- C. CT uses x-rays and Nuclear Medicine uses gamma rays, both being high energy photons whose spectra actually overlap.
- D. CT generally images anatomy with relatively high resolution and Nuclear Medicine generally images physiological function with relatively low resolution.
- E. Both modalities involve radiation risk to the patient.

Explanation: All are true.

[*imaging0292.mcq*]

44. Metastable technetium, or Tc-99m, has some desirable properties for a radiotracer, including which of the following?

- I. It can be produced cheaply on the hospital site for immediate use.
- II. Its decay yields high-energy photons clustered around a particular energy, allowing for specific detection.
- III. Its half life is long enough to last through a study but short enough so that the patient can be discharged in a reasonable time

- A. I, II, and III
- B. I and II
- C. I and III
- D. II and III
- E. II only

Explanation: All statements are true.

[*imaging0350.mcq*]

45. *Unlike* in nuclear medicine, in X-ray based imaging modalities,

- A. attenuation by tissue is the desired imaging parameter.
- B. signal can be increased by increasing the radiation dose.
- C. one or more crystals are used to convert high energy photons into light photons.
- D. electromagnetic radiation, not particulate radiation, is used to image.
- E. tomographic slices may be reconstructed by combining radiation detected along multiple linear paths.

Explanation: In nuclear medicine, attenuation is unwanted, since the total radioactivity is the desired imaging parameter. In CT or planar X-ray images, radiation is introduced from outside and attenuation measured.

[*imaging0351.mcq*]

46. Which of the following statements is *false* about Anger cameras?

- A. Average rates, rather than individual counts, of the gamma photons are all that are measured.
- B. Lead septa are required to generate a projection image
- C. Each gamma particle produces a scintillation consisting of many light photons.
- D. The contribution from Compton scattering to the image is reduced by analyzing the pulse height of the combined responses of the photomultiplier tubes to each detected gamma particle.
- E. Multiple photomultiplier tubes are arranged in a grid behind a large crystal that act in concert to determine the location of the incoming photons with a spatial resolution greater than that of the tubes.

Explanation: Individual gamma photons are indeed counted and located.

[*imaging0352.mcq*]

47. Which of the following is (are) *true* about the “line of stability” for nuclides?

- I. Spontaneous nuclear decay tends to move towards it.
- II. Positron emitters are on one side of it, while beta emitters are on the other.
- III. At higher atomic number, it shows that the number of neutrons tends to be larger than the number of protons.

- A. I, II, and III.
- B. I and II.
- C. I and III.
- D. II and III.
- E. Only I.

Explanation: All are true.

[*imaging0353.mcq*]

48. Which of the following statements about combined PET/CT scanners is *false* (or all are true)?

- A. The primarily anatomical, lower-resolution information from the CT scanner is combined with the primarily physiological, higher-resolution information from the PET scanner.
- B. Registration of the two imaging modalities is greatly facilitated since the patient only needs to be slid a short distance between the actual scanners.
- C. The CT scanner is used to determine the attenuation along each Line of Response in the PET scanner.
- D. Virtually every PET scanner sold today also contains a CT scanner.
- E. All are true.

Explanation: The primarily anatomical *higher-resolution* information from the CT scanner is combined with the primarily physiological *lower-resolution* information from the PET scanner.

[*imaging0354.mcq*]

49. Metastable technetium, or Tc-99m, has some desirable properties for a radiotracer, including which of the following?

- I. It can be produced cheaply on the hospital site for immediate use.
- II. Its decay yields high-energy electrons, known as “beta” particles.
- III. Its half life is long enough to last through a study but short enough so that the patient can be discharged in a reasonable time

- A. I and III
- B. I and II
- C. I, II, and III
- D. II and III
- E. II only

Explanation: Statement II is false. This is an example of metastable isomeric transition, not beta-decay.

[*imaging0414.mcq*]

50. Which of the following statements about combined PET/CT scanners is *false* (or all are true)?

- A. The primarily physiological, higher-resolution information from the CT scanner is combined with the primarily anatomical, lower-resolution information from the PET scanner.
- B. Registration of the two imaging modalities is greatly facilitated since the patient only needs to be slid a short distance between the actual scanners.
- C. The CT scanner is used to determine the attenuation along each Line of Response in the PET scanner.
- D. Virtually every PET scanner sold today also contains a CT scanner.
- E. All are true.

Explanation: The primarily *anatomical* higher-resolution information from the CT scanner is combined with the primarily *physiological* lower-resolution information from the PET scanner.

[*imaging0415.mcq*]

51. Which of the following statements is *false* about Anger cameras?

- A. Lead septa are not required to generate a projection image.
- B. Individual gamma photons are counted and located.
- C. Each gamma particle produces a scintillation consisting of many light photons.
- D. The contribution from Compton scattering to the image is reduced by analyzing the pulse height of the combined responses of the photomultiplier tubes to each detected gamma particle.
- E. Multiple photomultiplier tubes are arranged in a grid behind a large crystal that act in concert to determine the location of the incoming photons with a spatial resolution greater than that of the tubes.

Explanation: Lead septa are indeed required to generate a projection image.

[*imaging0416.mcq*]

52. The following are true about positron emitters, *except*, or all are true

- A. All are true.
- B. They include atoms with low atomic number typically found in normal organic molecules, such as carbon and oxygen.
- C. Their decay leads to the generation of antimatter and subsequently to the creation of two 511 keV gamma photons moving in directions approximately 180 degrees apart.
- D. They are used in devices that nowadays typically also contain a CT scanner.
- E. They are unstable because they have too few neutrons.

Explanation: All are true.

[*imaging0417.mcq*]

53. Which of the following statements is *false* about radioactive decay (or all are true)?

- A. Half-life is fifty percent of the time it takes for all of the sample to decay.
- B. Its statistics is governed by the Poisson distribution.
- C. All are true.
- D. The radioactivity (how many radioactive atoms are undergoing decay every second) in a given sample decreases with time as an inverse exponential.
- E. The number of radioactive atoms remaining in a given sample decreases with time as an inverse exponential.

Explanation: Half-life is the time it takes for fifty percent of the sample to decay. Both D and E are true, since they are related by a λ , the decay constant.

[*imaging0418.mcq*]

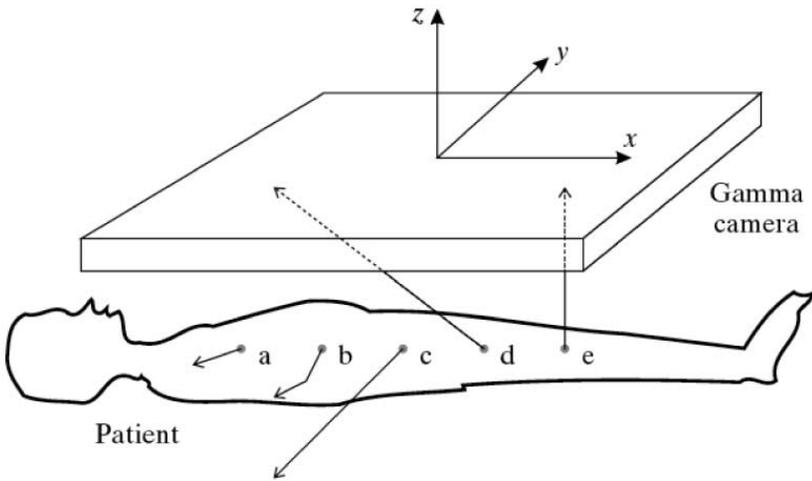
54. Which of the following statements is *false* about photomultiplier tubes (or all are true)?

- A. All are true.
- B. Used in an Anger camera to produce an electrical signal whose pulse height is related to the number of light photons generated by a gamma event.
- C. Is designed to be extremely sensitive to light photons.
- D. Uses a series of dynodes at successively more positive voltage within the tube to create increasing numbers of cascading electrons from an initial few electrons.
- E. Uses a photocathode to generate electrons from incoming photons.

Explanation: That's how it works.

[*imaging0419.mcq*]

55. In the following diagram on an Anger camera in action, which of the gamma photons will *increase* the signal to noise ratio? (Note: the lower case letters in the diagram do *not* correspond to the upper case letters for the answers!).

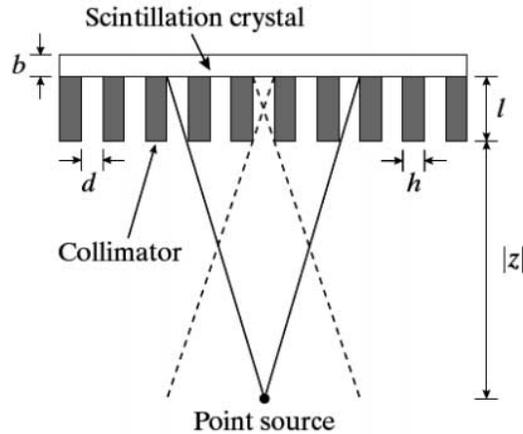


- A. 'e' in the diagram.
- B. 'a' in the diagram.
- C. 'b' in the diagram.
- D. 'c' in the diagram.
- E. 'd' in the diagram.

Explanation: Gamma photons a, b, and c do not reach the detector, so do not increase the signal. Photon d does reach the detector, but at the wrong location (assuming it makes it through the collimator), and so it constitutes noise, not signal.

[*imaging0420.mcq*]

56. The collimator geometry configuration of Anger camera is shown in the image below. The collimator resolution is given by $R_C = \frac{d}{l}(l + b + |z|)$ and the sensitivity of collimator is given by $\epsilon = \left(\frac{Kd^2}{l_e(d+h)}\right)^2$, where d is the collimator hole diameter, l is the collimator hole length, b is the scintillator depth and h is the collimator length. Which of the following is *true* (or all are incorrect)?



- A. There is a trade-off between resolution and sensitivity.
- B. Collimator resolution degrades as $|z|$ decreases.
- C. The collimator can actually increase the number of gamma photons hitting the scintillation crystal.
- D. Sensitivity decreases with greater $|z|$
- E. All are incorrect.

Explanation: Collimator resolution degrades as $|z|$ *increases*. No collimator can actually let more gamma photons through than initially hit it. Sensitivity stays constant with $|z|$, as is seen in the equation given, and understood by the fact that with greater $|z|$ a larger area of the crystal is irradiated, canceling the loss of flux with distance.

[*imaging0440.mcq*]

57. The following descriptions about the instrumentation of SPECT and PET are all incorrect, *except*

- A. The advantage of dynamic frame mode acquisition is that it applies the temporal succession of frame mode images and needs less storage space compared with static frame mode acquisition.
- B. Thicker crystals detect more radiation than thinner crystals, and they have better resolution.
- C. The number of electrons at the output of a photomultiplier tube is the same as the number of light photons at the input.
- D. The accurate position (X, Y) of the event is equal to the location of photomultiplier tube having the largest amplitude.
- E. Both PET and SPECT require a collimator to allow only the specific photons traveling in an appropriate direction.

Explanation: Thicker crystals detect more radiation than thinner crystals, but they have poorer resolution. The number of electrons at the output of a photomultiplier tube is much larger than the number of light photons at the input. Using the largest amplitude only gives as the approximate position where the event occurs; we need to use center of mass to calculate accurate position. Only SPECT needs collimator.

[*imaging0441.mcq*]

58. Which of the following is *false* about scintillations (or all of the others are true)?

- A. It occurs within the body providing a natural amplification of the number of useful high-energy photons reaching the detector.
- B. They are generally the first step within a detector in using high-energy photons (X-ray or gamma) to create an image.
- C. Like fluorescence, lower energy photons are created from higher energy photons.
- D. Unlike fluorescence, the higher energy photon causes ionization and many lower energy photons are formed from a single higher energy photon.
- E. All of the others are true.

Explanation: Scintillation within the body, if it were to occur at all, would be very bad for the patient and not produce other useful high-energy patients.

[*imaging0444.mcq*]

59. Which of the following statements is *false* about this matrix (or all are true):

$$\begin{bmatrix} 1 & 0 & 2 \\ 0 & 1 & 3 \\ 0 & 0 & 1 \end{bmatrix}$$

- A. All are true.
- B. It performs pure translation (no rotation or scaling).
- C. It operates in homogeneous coordinates.
- D. It transforms coordinates for 2-dimensional locations.
- E. It performs a geometric (rigid body) transformation.

Explanation: The matrix translates a 2D location in the form of a homogeneous vector (which is scaled to keep its last element equal to 1) by +2 in the x direction and +3 in the y direction.

[*imaging0473.mcq*]

60. Which of the following statements is *false* about photomultiplier tubes (or all are true)?

- A. Is designed to be extremely sensitive to high energy photons, including gamma and x-ray photons.
- B. Used in an Anger camera to produce an electrical signal whose pulse height is related to the number of light photons generated by a gamma event.
- C. All are true.
- D. Uses a series of dynodes at successively more positive voltage within the tube to create increasing numbers of cascading electrons from an initial few electrons.
- E. Uses a photocathode to generate electrons from incoming photons.

Explanation: Photomultiplier tubes are designed to detect light photons. To detect gamma or x-ray photons, a photomultiplier tube requires a scintillation crystal or other device to produce light photons.

[*imaging0474.mcq*]

61. Which of the following statements is (are) *true* about the analysis of pulse height in the detection of gamma particles by Anger cameras?

I - It permits rejection of Compton scattering.

II - It permits rejection of multiple simultaneous gamma photons.

III - It reports the total number of light photons hitting a single photomultiplier tube.

A. I and II

B. II and III

C. I and III

D. I, II, and III

E. Only I.

Explanation: III is false. The pulse height generally results from summing the signals generated from a group of photomultiplier tubes.

[*imaging0475.mcq*]

62. Which of the following is (are) *true* about both SPECT and PET?

I. Each has a corresponding projection modality.

II. Each is a tomographic imaging modality based on the emission of gamma particles from within the patient.

III. Each involves the annihilation of matter and antimatter

A. only II.

B. I and II.

C. I and III.

D. II and III.

E. I, II, and III.

Explanation: PET is not based on a projection modality, though SPECT is. Only PET involves the annihilation of matter and antimatter.

[*imaging0476.mcq*]

63. *Unlike* CT, in nuclear medicine

A. Bremsstrahlung is not used to produce high-energy photons.

B. signal can be increased by increasing the radiation dose.

C. crystals are used to convert high energy photons into light photons.

D. electromagnetic radiation, not particulate radiation, is used to image.

E. causing cancer is not a risk.

Explanation: Bremsstrahlung is only used in x-ray and CT. High-energy photons are due to nuclear events in nuclear medicine.

[*imaging0477.mcq*]

64. The following modes of decay are used in Nuclear Medicine imaging *except*, or all are used.

- A. Alpha decay.
- B. Positron decay.
- C. Isomeric transition.
- D. Beta decay.
- E. All are used.

Explanation: Beta decay is not often used, although it is occasionally, as in I-131. Alpha decay is never used, because an alpha particle (2 protons + 2 neutrons) is extremely destructive.

[*imaging0478.mcq*]

65. Regarding single photon emitters, which of the following statements about the equation below is *false* (or all are true)?

$$\phi(x, y) = \int_{-\infty}^0 \frac{A(x, y, z)}{4\pi z^2} \exp \left\{ - \int_z^0 \mu(x, y, z'; E) dz' \right\} dz$$

- A. $A(x, y, z)$ is the attenuation at location (x, y, z) .
- B. It assumes mono-energetic photons, which is a good assumption assuming a given nuclear decay.
- C. It assumes a heterogeneous tissue in terms of attenuation, and a perfect collimator.
- D. The contribution from each location falls off as the square of the distance, and is attenuated by the material along the line between that location and the detector.
- E. All are true.

Explanation: $A(x, y, z)$ is the radioactivity (number of atoms disintegrating per unit time) at location (x, y, z) .

[*imaging0499.mcq*]

66. Regarding PET, which of the following statements about the equation below is *false* (or all are true)?

$$N_c(s_0) = N_0 \exp \left\{ - \int_{-R}^R \mu(x(s'), y(s'); E) ds' \right\}$$

- A. All are true.
- B. It assumes no random coincidences at the 2 detectors from different positron decays.
- C. It assumes a heterogeneous tissue in terms of attenuation.
- D. The effect of attenuation along a given line of response on the number of coincident detections is independent of where the positron decay occurs along the line of response.
- E. It assumes mono-energetic photons, which is a good assumption with positron decay.

Explanation:

[*imaging0500.mcq*]