BioE 1330 - Review Chapters 7, 8, and 9 (Nuclear Medicine) 1/17/2011

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.

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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 isotopes, the following are true:

I. They have the same number of protons.
II. They have the same atomic mass.
III. They are chemically identical.

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. 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. I, II, and III

B. I and III

C. only III

D. II and III

E. I and II

11. 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. only III

D. II and III

E. I and III

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

A. 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.

B. An uncertainty always exists as to the location of the positron decay due to the distance the positron travels before annihilating with an electron.

C. PET is one the two major forms of Emission Computed Tomography, with SPECT being the other.

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. 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*.

13. 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. II and III

C. I and II

D. I and III

E. I

14. 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. Radioactive decay leads to atoms with lower binding energy.

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. 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).

15. 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. II and III.

B. I and III.

C. I and II.

D. only II.

E. I, II, and III.

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

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

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

C. reducing the distance between the desired organ and the detector reduces total attenuation along the path of the photon.

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

E. tomographic slices may be reconstructed by combining radiation detected along multiple linear paths.

17. 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. None of the other ranges contain the correct value

B. Between 10-30 seconds

C. Between 3-10 seconds

D. Between 1-3 seconds

E. Between 30-100 seconds

18. 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 and III

C. I, II, and III

D. II only

E. II and III

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

A. Increasing the obesity of the patient

B. Increasing the distance between the patient and the camera

C. None of the other choices

D. Increasing the length of the lead septa in the collimator

E. Increasing the thickness of the scintillation crystal

20. 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 1 and 30 seconds

B. Between 300 and 1000 seconds

C. Between 30 and 100 seconds

D. More than 1000 seconds

E. Between 100 and 300 seconds

21. 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 - electron stream - light photon - voltage in a computer

B. Radiotracer - α-particle - electron stream - light photon - voltage in a computer

C. None of the other choices

D. Radiotracer - α-particle - light photon - electron stream - voltage in a computer

E. Radiotracer - γ-ray - light photon - electron stream - voltage in a computer

22. The number of γ-rays striking a scintillation crystal during a nuclear medicine scan is counted to be approximately 10^4 per second. The SNR of the scan is 50:1. The dose of radioactivity administered is 2 mCi of Tc-99m. Based on the assumption that radioactive decay is a Poisson process, approximately what is the standard deviation of the number of photons striking the crystal each second? (1 Ci = 3.7×10^{10} atomic disintegrations per second, Avogadro's number is 6.02×10^{23} atoms per mole.)

A. 50

B. 100

C. 500

D. 10

E. 1000

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 and SPECT scanners can use the same scintillation crystal to detect γ-rays without compromising either application.

III PET and SPECT both use reconstruction methods to produce the images viewed by doctors.

A. II and III

B. I and III

C. I only

D. I, II, and III

E. II only

25. 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. λ_P

B. $1/\lambda_P$

C. $\ln 2/\lambda_P$

D. $2/\lambda_P$

E. $\lambda_P/\ln 2$

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

A. Planar scintigraphy is the nuclear medicine analog of projection radiography.

B. All of them are TRUE.

C. Event positioning is based on a center-of-mass calculation; unlike radiographic image formation, this takes place on a photon-by-photon basis.

D. Radiotracers make use of radionuclides that emit radiation of appropriate type and energy, have half-lives that are appropriate, and are chemically inert.

E. Nuclear medicine produces images that depict the distribution of a radiotracers; this distribution is generally governed by body function, and not simply structure.

27. 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. 1/4 of original intensity

B. Same

C. Doubles

D. 1/2 of original intensity

E. Cannot be determined from given information

28. 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. 15 min.

B. 30 min.

C. 25 min.

D. 20 min.

E. 10 min.

29. 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 - 1, e - 5

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

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

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

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

30. Which of the following statements are TRUE about detector crystals 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 - Multiple small detectors are arranged in a grid to permit determination of the location of the radiation.
IV - Gamma rays produce scintillations in the crystals consisting of many light photons.

A. II and III

B. II and IV

C. None of them

D. I and IV

E. I and III

31. Which of the following statements is FALSE?

A. In PET imaging the attenuation factor depends on the location of the activity along the imaging line.

B. None of them

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. Since the radioactivity does not always occur at the center of the PET scanner, the traveling times of the two coincident gamma photons are not the same.

32. Which one of the followig 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. None of them

C. 1,2,3

D. 2,3,4

E. All of them

33. 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 II

B. II, and III

C. III

D. I and III

E. I, II, and III

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

A. They include atoms with low atomic number typically found in normal organic molecules, such as carbon and oxygen.

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 are used in devices that nowadays typically also contain a CT scanner.

E. They are used in SPECT to create tomographic images.

35. 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. 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.

C. 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.

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 of response the radioactivity occurs.

E. None of the others is false.

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

A. 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.

B. Lead septa are required to generate a projection image

C. Multiple photomultiplier tubes, one for each pixel in the image, are arranged in a grid behind a large crystal.

D. Each gamma particle produces a scintillation consisting of many light photons.

E. Gating acquisition to the electrocardiogram reduces motion artifact from cardiac motion.

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

A. Decreasing the length of the lead septa in the collimator

B. None of the other choices

C. Increasing the distance between the patient and the camera

D. Increasing the distance between the lead septa in the collimator

E. Decreasing the thickness of the scintillation crystal

38. 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. I and III

C. I and II

D. Only II.

E. II and III

39. 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, II, and III.

D. I and III.

E. II and III.

40. 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 atoms actual mass.
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. Only I.

E. II and III.

41. 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 number it shows that the atomic mass tends to be twice the atomic number.
III. It higher atomic number, 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.

42. 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 relies on *transmission* through the body and Nuclear Medicine on *emission* from within the body.

D. All are true.

E. CT generally images anatomy with relatively high resolution and Nuclear Medicine generally images physiological function with relatively low resolution.

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BioE 1330 - Review Chapters 7, 8, and 9 (Nuclear Medicine) 1/17/2011
Answer Sheet - Correct answer is A for all questions

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 isotopes, the following are true:

I. They have the same number of protons.
II. They have the same atomic mass.
III. They are chemically identical.

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. 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*]

11. 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*]

12. 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*]

13. 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*]

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

A. Radioactive decay leads to atoms with lower binding energy.

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*]

15. 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*]

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

A. reducing the distance between the desired organ and the detector 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 detector. 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*]

17. 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*]

18. 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*]

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

A. Increasing the length of the lead septa in the collimator

B. Increasing the distance between the patient and the camera

C. Increasing the thickness of the scintillation crystal

D. Increasing the obesity of the patient

E. None of the other choices

Explanation: Lengthening the lead septa will prevent a larger fraction of scattered photons from reaching the detection circuitry, resulting in increased resolution. The other options would actually decrease the spatial resolution of the camera.
[*imaging0176.mcq*]

20. You have a sample of a radioactive element that has activity A = 256 mCi (milliCuries) at time t = 0 seconds. Its decay constant is $\lambda = 10^{-2}\mathrm{s}^{-1}$. 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 $t = \frac{1}{\lambda} \ln(\frac{A_0}{A_t}) = 230$ seconds.
[*imaging0177.mcq*]

21. 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*]

22. The number of γ-rays striking a scintillation crystal during a nuclear medicine scan is counted to be approximately 10^4 per second. The SNR of the scan is 50:1. The dose of radioactivity administered is 2 mCi of Tc-99m. Based on the assumption that radioactive decay is a Poisson process, approximately what is the standard deviation of the number of photons striking the crystal each second? (1 Ci = 3.7×10^{10} atomic disintegrations per second, Avogadro's number is 6.02×10^{23} atoms per mole.)

A. 100

B. 50

C. 10

D. 500

E. 1000

Explanation: If there are N counts per second, the standard deviation for a Poisson process is approximated by $\sqrt{N}$, or 100. The other information is not necessary to solve the problem.
[*imaging0179.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 and SPECT scanners can use the same scintillation crystal to detect γ-rays without compromising either application.

III PET and SPECT both use reconstruction methods to produce the images viewed by doctors.

A. I and III

B. I, II, and III

C. I only

D. II and III

E. II only

Explanation: PET and SPECT use γ-rays with different energy distributions (e.g., Tc-99m at 140 KeV vs. the 511 KeV generated by positron decay), and thus require different scintillation crystals. The crystals are chosen for their increased response to the particular energy spectrum of the γ-ray being used.

Alternate acceptable answer: B

Errata: II is somewhat ambiguous, since SPECT cameras can indeed be used as PET scanner, although without as good performance. So B could also be considered correct.
[*imaging0181.mcq*]

25. 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*]

26. Which one of the following statements is TRUE (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 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*]

27. 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.

Alternate acceptable answer: C

Errata: Many students also chose C, because it wasn't clear that a homogeneous beam across the entire detector was assumed.
[*imaging0209.mcq*]

28. 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: For solution look at example 9.1
[*imaging0210.mcq*]

29. 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*]

30. Which of the following statements are TRUE about detector crystals 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 - Multiple small detectors are arranged in a grid to permit determination of the location of the radiation.
IV - Gamma rays produce scintillations in the crystals consisting of many light photons.

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. III is false; Anger cameras use one or two large crystal detectors.
[*imaging0213.mcq*]

31. Which of the following statements is FALSE?

A. In PET imaging the attenuation factor depends on the location of the activity along the imaging line.

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. Since the radioactivity does not always occur at the center of the PET scanner, the traveling times of the two coincident gamma photons are not the same.

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 imaging line, because the total path traveled by both gamma particles remains the same along a given imaging line.

Alternate acceptable answer: C

Errata: Answer C is misleading, in that yes, the traveling time is slightly different, but that is not important in the image reconstruction process; they are still considered coincident.
[*imaging0214.mcq*]

32. Which one of the followig 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*]

33. 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*]

34. 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*]

35. 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*]

36. 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*]

37. 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*]

38. 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*]

39. 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*]

40. 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 atoms actual mass.
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*]

41. 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 number it shows that the atomic mass tends to be twice the atomic number.
III. It higher atomic number, 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 higher atomic number the number of neutrons tends to be *larger* than the number of protons.
[*imaging0269.mcq*]

42. 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*]