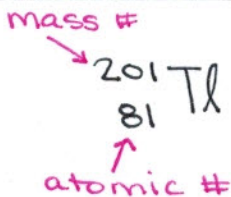# Chapter 5 – Nuclear Chemistry – Practice Problems
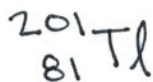
1. Fill in the missing information in the chart:

| Medical Use | Atomic symbol | Mass number | Number of protons | Number of neutrons |
|---|---|---|---|---|
| Heart imaging | $^{201}_{81}Tl$ | 201 | 81 | 120 |
| Abdominal scan | $^{60}_{27}Co$ | 60 | 27 | 33 |
| Hyperthyroidism | $^{67}_{31}Ga$ | 67 | 31 | 36 |
| Radiation therapy | $^{131}_{53}I$ | 131 | 53 | 78 |
| Leukemia treatment | $^{32}_{15}P$ | 32 | 15 | 17 |

mass #

$^{201}_{81}Tl$

atomic #

atomic # = # protons

mass # = # protons + # neutrons

Row 1

$^{201}_{81}Tl$     81 protons     201 - 81 = 120 neutrons
         201 mass #

Row 2
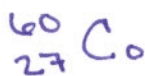
          cobalt
$^{60}_{27}Co$     27 protons     60 - 27 = 33 neutrons
         60 mass #

Row 3

                         31 protons     36 neutrons
$^{67}_{31}Ga$     31 + 36 = 67 mass #

Row 4
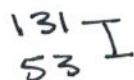
$^{131}_{53}I$     53 protons     131 - 53 = 78 neutrons
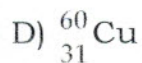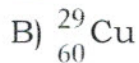         131 mass #
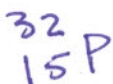
Row 5     32 - 17 = 15 protons     17 neutrons

$^{32}_{15}P$

         32 mass #

2. What is the nuclear symbol for a radioactive isotope of copper with a mass number of 60?

A) $^{60}_{29}Cu$

B) $^{29}_{60}Cu$

C) 29Cu

D) $^{60}_{31}Cu$

E) $^{31}_{29}Cu$

$^{60}_{29}Cu$
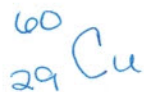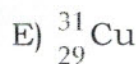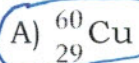
from p. table, copper's atomic # = 29

3. Identify the following based on the mass number and atomic number: $^{4}_{2}X$
A) alpha particle
B) beta particle
C) positron particle
D) gamma ray
E) neutron

types of radiation

$^{4}_{2}He$ - alpha

$^{0}_{-1}e$ - beta
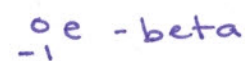
$^{0}_{+1}e$ - positron

4. Identify the following based on the mass number and atomic number: $^{1}_{0}X$
A) alpha particle
B) beta particle
C) positron particle
D) gamma ray
E) neutron

$^{0}_{0}\gamma$ - gamma

$^{1}_{1}H$ - proton

$^{1}_{0}n$ - neutron

*types of radiation*

5. Identify the following based on the mass number and atomic number: $_1^1X$
A) alpha particle
B) beta particle
C) electron
D) proton  *(circled)*
E) neutron

$_2^4He$ - alpha

$_{-1}^0e$ - beta

$_{+1}^0e$ - positron

6. Identify the following based on the mass number and atomic number: $_0^0X$
A) alpha particle
B) beta particle
C) positron particle
D) gamma ray  *(circled)*
E) neutron

$_0^0\gamma$ - gamma

$_1^1H$ - proton

$_0^1n$ - neutron

7. Gamma rays require the heaviest shielding of all the common types of nuclear radiation because gamma rays have the
A) highest energy.  *(circled)*
B) most intense color.
C) lowest energy.
D) largest particles.  > alpha particles
E) heaviest particles.

8. The symbol $_{+1}^0e$ is a symbol used for a(n)

A) proton.
B) positron.  *(circled)*
C) gamma ray.
D) beta particle.
E) alpha particle.

9. Match the type of radiation (**1 to 3**) with each of the following statements:

1. Alpha particle
2. beta particle
3. gamma radiation

a. penetrates farthest into skin and body tissue – gamma
b. shielding protection includes lab coats and gloves – beta (and alpha)
c. travels only a short distance by air  alpha

10. Match the type of radiation (**1 to 3**) with each of the following statements:

1. Alpha particle
2. beta particle
3. gamma radiation

a. does not penetrate skin **alpha**
b. shielding protection includes lead or thick concrete **gamma**
c. can be very harmful if ingested **alpha**

11. The nuclear symbol of helium, $_2^4 He$, is also the symbol for designating a(n)
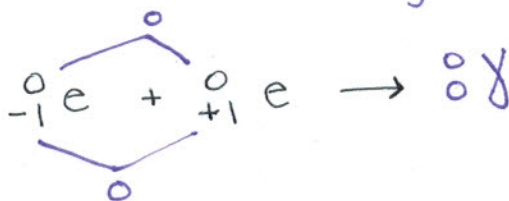
A) proton.
B) neutron.
C) gamma ray.
D) beta particle.
(E) alpha particle.

12. When a beta particle and positron combine, what particle is made?

$_{-1}^0 e + {}_{+1}^0 e \rightarrow ?$

A) proton.
B) neutron.
(C) gamma ray.
D) beta particle.
E) alpha particle.
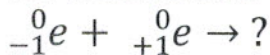
total mass # on left = right
total atomic #/charge on left = right

$_{-1}^0 e + {}_{+1}^0 e \rightarrow {}_0^0 \gamma$     ($\gamma$ always goes w/ $_0^0$)
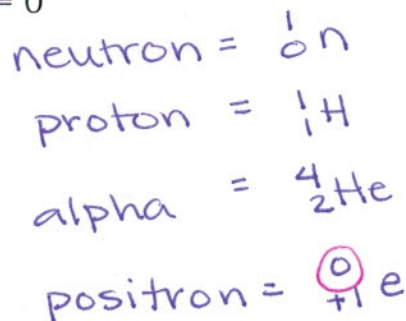
13. The symbol $_{-1}^0 e$ is a symbol used for a(n)

A) proton.
B) neutron.
C) gamma ray.
(D) beta particle.
E) alpha particle.
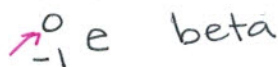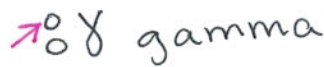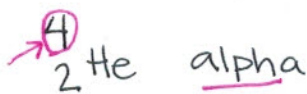
14. Which of the following have mass # = 0
A) neutron
B) proton
C) alpha particle
(D) positron particle
E) More than one of the above

neutron = $_0^1 n$

proton = $_1^1 H$

alpha = $_2^4 He$

positron = $_{+1}^0 e$

15. Which type of radiation has the largest mass?
A) beta particle
B) gamma rays
C) alpha particle
D) neutron
E) positron particle

$_2^4He$ alpha

$_{-1}^0e$ beta

$_{+1}^0e$ positron

$_0^0\gamma$ gamma

$_1^1H$ or $_1^1p$ proton

$_0^1n$ neutron

16. The process in which a nucleus spontaneously breaks down by emitting radiation is known as
A) transmutation.
B) transformation.
C) fusion.
D) a chain reaction.
E) radioactive decay.

17. A nuclear equation is balanced when
A) the same elements are found on both sides of the equation.
B) the sum of the mass numbers and the sum of the atomic numbers of the particles and atoms are the same on both sides of the equation.
C) the same particles and atoms are on both sides of the equation.
D) different particles and atoms are on both sides of the equation.
E) the charges of the particles and atoms are the same on both sides of the equation.

18. Iodine-131 decays by beta decay to
A) iodine-132.
B) tellurium-131.
C) iodine-130.
D) bromine-131.
E) xenon-131.

$_{-1}^0e$

$=131$

$$_{53}^{131}I \rightarrow _{-1}^0e + _{54}^{131}Xe$$

$=53$
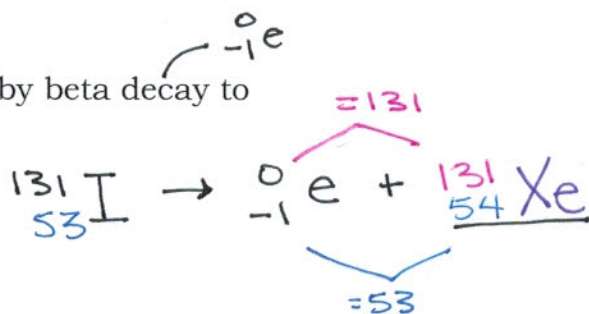
mass #'s must add to 131 on both sides
atomic # of I = 53. atomic #'s must add
to 53 on both sides.
atomic # 54 = Xe on p.table.

19. Finish the equation for positron emission: $_1^1p \rightarrow _0^1n + ?$
A) beta particle
B) gamma rays
C) alpha particle
D) neutron
E) positron particle

$=1$

$$_1^1p \rightarrow _0^1 + _1^0e$$

$=1$

1. Write the incomplete nuclear equation.
2. Determine missing mass #
3. Determine missing atomic #
4. Determine symbol of the new nucleus.
5. Complete nuclear equation.
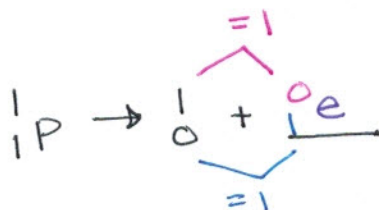
mass #'s must add to 1 on both sides
atomic #'s must add to 1 on both sides
$_1^0$ represents a positron $_{+1}^0e$

20. What is the radioactive particle released in the following nuclear equation?

$$^{139}_{74}W \rightarrow \,^{155}_{72}Hf + ?$$
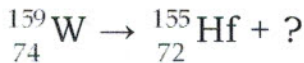
A) alpha particle
B) beta particle
C) gamma ray
D) proton
E) neutron

$$^{159}_{74}W \rightarrow \,^{155}_{72}Hf + \,^{4}_{2}He$$

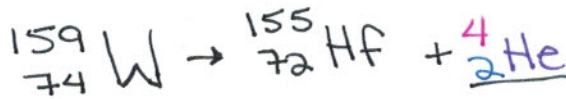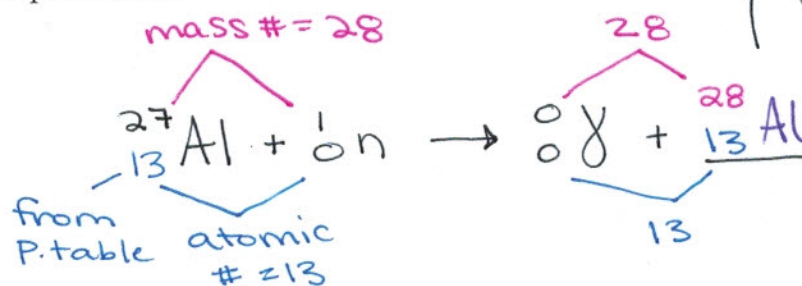total mass # = 159

total atomic # = 74

$\frac{4}{2}$ = alpha particle

1. write the incomplete nuclear equation
2. Determine missing mass #
3. Determine missing atomic #
4. Determine symbol of new nucleus
5. Complete equation.

21. When aluminum-27 is bombarded with a neutron, a gamma ray is emitted. What radioactive isotope is produced?

A) silicon-27
B) silicon-28
C) aluminum-28
D) magnesium-27
E) magnesium-28

mass # = 28

$$^{27}_{13}Al + \,^{1}_{0}n \rightarrow \,^{0}_{0}\gamma + \,^{28}_{13}Al$$

from P. table    atomic # = 13

28

13

22. The nuclear reaction shown below is an example of what type of process?

$$^{224}_{90}Th \rightarrow \,^{220}_{88}Rn + \,^{4}_{2}He$$

alpha

A) fusion
B) fission
C) translation
D) alpha decay
E) beta decay

$^{0}_{-1}e$
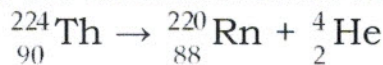
23. Nitrogen-17 is a beta emitter. What is the isotope produced in the radioactive decay?

A) $^{18}_{6}C$

B) $^{13}_{5}B$

C) $^{18}_{7}N$

D) $^{13}_{9}F$

E) $^{17}_{8}O$

mass # = 17        = 17

$$^{17}_{7}N \rightarrow \,^{0}_{-1}e + \,^{17}_{8}O$$

atomic # 7    = 7

atomic # 8 = Oxygen

from p. table

24. What is missing in the nuclear reaction shown below?

$$^{10}_{5}B + ^{4}_{2}He \rightarrow \underline{\qquad} + ^{1}_{0}n$$
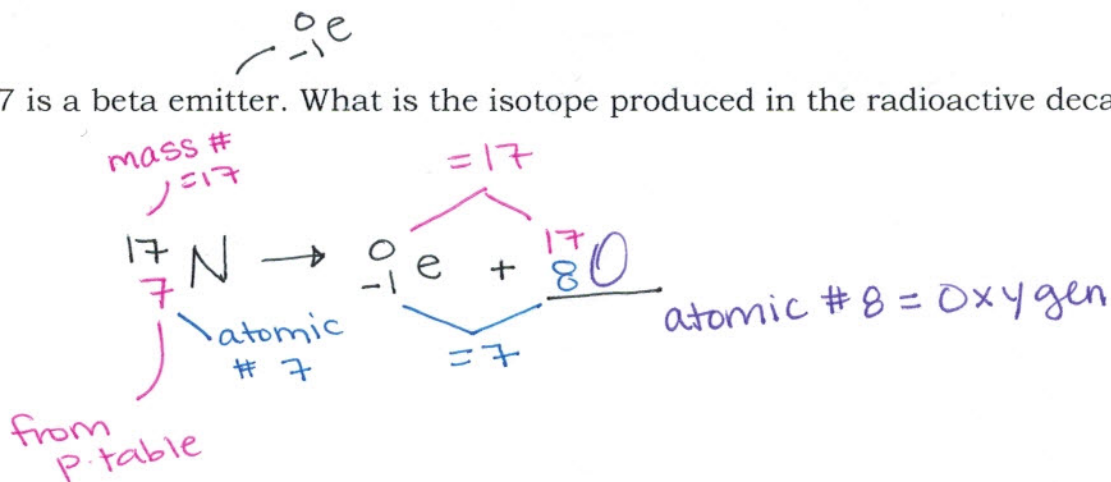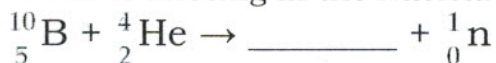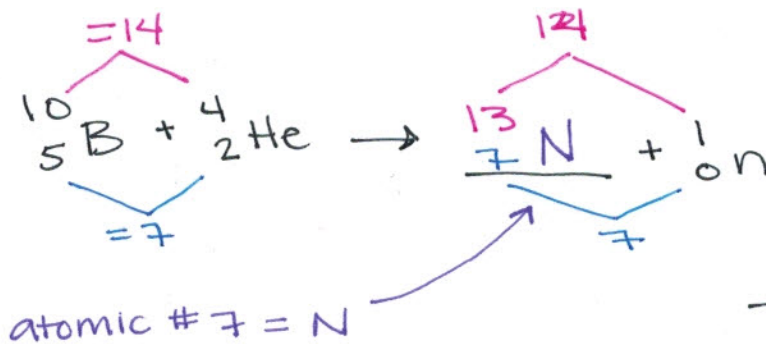
A) a neutron

B) $^{13}_{7}B$

C) $^{14}_{7}N$

D) $^{13}_{7}N$

E) $^{13}_{5}N$

(handwritten annotations)

$$=14 \qquad 14$$
$$^{10}_{5}B + ^{4}_{2}He \rightarrow ^{13}_{7}N + ^{1}_{0}n$$
$$=7 \qquad 7$$

atomic # 7 = N

1. write the incomplete equation.

2. mass # equal on both sides

3. atomic # equal on both sides

4. Determine symbol

5. Complete equation

25. What is the radiation formed?

$$^{1}_{0}n \rightarrow ^{1}_{1}H + ?$$
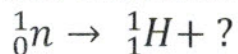
A) alpha particle

B) beta particle

C) positron

D) gamma ray

E) proton
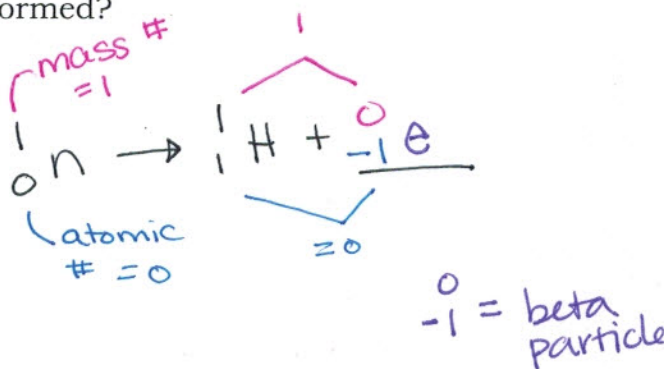
(handwritten annotations)

mass # = 1
$$^{1}_{0}n \rightarrow ^{1}_{1}H + ^{0}_{-1}e$$
atomic # = 0 $\qquad$ = 0

$^{0}_{-1}$ = beta particle

26. What is missing in the nuclear reaction shown below?

$$^{10}_{5}B + ^{4}_{2}He \rightarrow ^{13}_{7}N + \underline{\qquad}$$
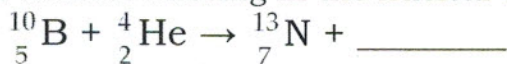
A) gamma radiation

B) a positron

C) a neutron

D) an alpha particle

E) a beta particle

(handwritten annotations)

$$14 \qquad 14$$
$$^{10}_{5}B + ^{4}_{2}He \rightarrow ^{13}_{7}N + ^{1}_{0}n$$
$$7 \qquad 7$$
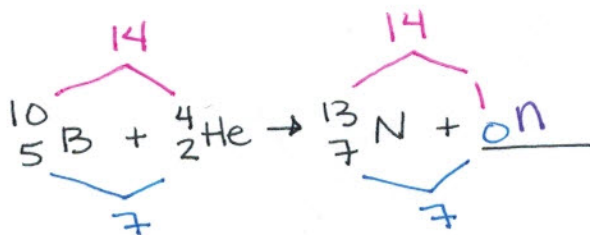
$^{1}_{0}$ = neutron

27. The product from the alpha decay of $^{235}_{92}U$ is

A) $^{235}_{93}Np.$

B) $^{239}_{94}Pu.$

C) $^{231}_{90}Th.$

D) $^{233}_{80}Ra.$

E) $^{236}_{92}U.$

(handwritten annotations)

mass # = 235 $\qquad$ 235
$$^{235}_{92}U \rightarrow ^{4}_{2}He + ^{231}_{90}Th$$
atomic # = 92 $\qquad$ 92

90 = thorium

28. What is missing in the nuclear reaction shown below?

$$^{66}_{30}Zn + ^1_1p \rightarrow \underline{\hspace{2cm}}$$

A) a proton

B) $^{67}_{31}Ga$

C) $^{66}_{31}Ga$

D) $^{67}_{31}Zn$

E) $^{65}_{29}Cu$



$$^{66}_{30}Zn + ^1_1P \rightarrow ^{67}_{31}Ga$$
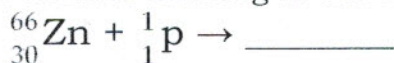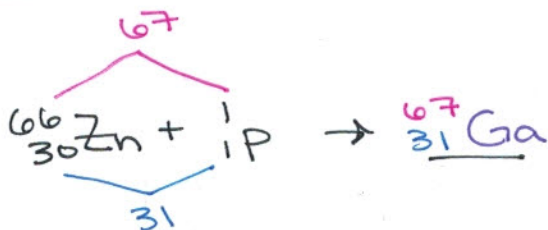
29. Write a balanced equation for the positron emission of the following: $^{15}_8O$

A) $^{15}_8O \rightarrow ^0_{+1}e + ^{15}_7N$

B) $^{15}_8O + ^0_{+1}e \rightarrow ^{15}_9N$

C) $^{15}_8O \rightarrow ^0_{-1}e + ^{15}_9F$

D) $^{15}_8O + ^0_{-1}e \rightarrow ^{15}_7N$

E) None of the above
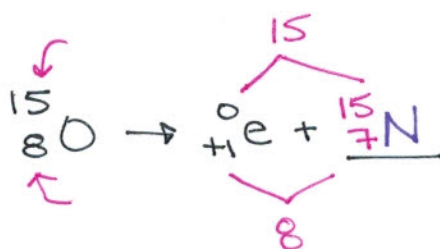


$$^{15}_8O \rightarrow ^0_{+1}e + ^{15}_7N$$

1. Write the incomplete equation

2. mass # equal on both sides

3. atomic # equal on both sides

4. Determine symbol

5. Complete equation.

30. The nuclear reaction

$$^{126}_{50}Sn \rightarrow ^{126}_{51}Sb + ?$$
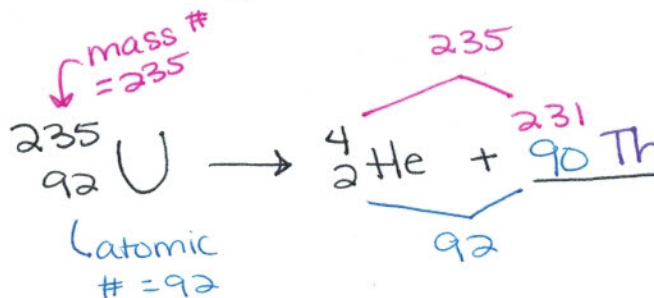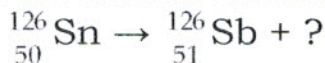
is an example of
A) fusion.
B) fission.
C) translation.
D) alpha decay.
E) beta decay.



$$^{126}_{50}Sn \rightarrow ^{126}_{51}Sb + ^0_{-1}e$$
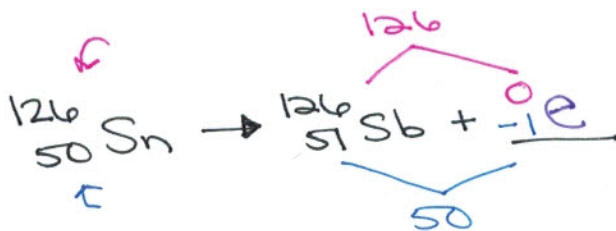
31. Write a balanced equation for the positron emission of Nitorgen-13

A) $^{13}_7N \rightarrow ^0_{+1}e + ^{13}_8O$

B) $^{13}_7N \rightarrow ^0_{+1}e + ^{13}_4Be$

C) $^{13}_5N \rightarrow ^0_{+1}e + ^{13}_4C$

D) $^{13}_7N \rightarrow ^0_{+1}e + ^{13}_6C$

E) $^{13}_7N \rightarrow ^0_{-1}e + ^{13}_8O$



$$^{13}_7N \rightarrow ^0_{+1}e + ^{13}_6C$$
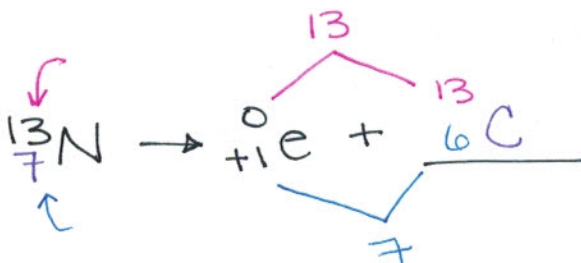
32. When a gamma ray is emitted from the nucleus of an atom, the nuclear mass
A) increases by two units.
B) decreases by one unit.
C) increases by one unit.
D) decreases by two units.
E) remains the same.

$$gamma = \,^{0}_{0}\gamma$$

33. Radium-226 decays by alpha decay to
A) barium-131.
B) cobalt-60.
C) carbon-14.
D) polonium-218.
E) radon-222.

$$\,^{226}_{88}Ra \rightarrow \,^{4}_{2}He + \,^{222}_{86}Rn$$

226

86 = radon
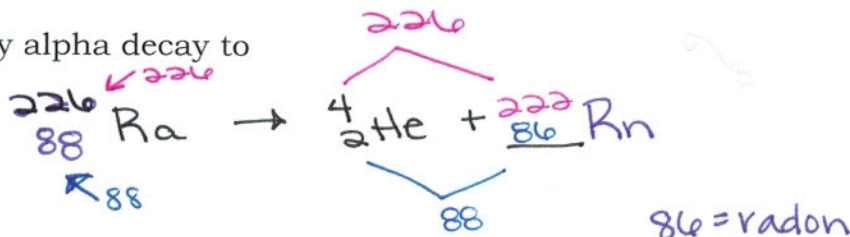
34. The recommended dosage of I-131 for a test is 4.2 microcuries per kg of body weight. How many mCi should be given to a 55 kg patient? (1 mCi = 1000 µCi)
A) 230 mCi
B) 0.23 mCi
C) 0.076 mCi
D) 760 mCi
E) 13.8 mCi

$$55 \, kg \rightarrow \mu Ci \rightarrow mCi$$

$$\frac{55 \, kg}{} \left| \frac{4.2 \, \mu Ci}{kg} \right| \frac{mCi}{1000 \, \mu Ci} = .23 \, mCi$$

35. Suppose a person absorbed 50 mrad of alpha radiation. What would be the equivalent dose in millirems? The biological effect factor of alpha radiation is 20.
A) 1 mrem
B) 1000 mrems
C) 2.5 mrems
D) 2500 mrems
E) 100 mrems

$$mrems = mrads \times factor$$
$$= (50 \, mrad)(20)$$
$$= 1000 \, mrems$$

36. A sample of cerium-141 for a diagnostic test was dissolved in saline solution to an activity of 4.5 mCi/mL. If the patient undergoing the test needs a dose of 10. mCi, how much of the solution should be injected into the patient?
A) 45 mL
B) .45 mL
C) 2.2 mL
D) 22 mL
E) 4.5 mL

$$\frac{10 \, mCi}{} \left| \frac{mL}{4.5 \, mCi} \right. = 2.2 \, mL$$

37. The unit used to measure the amount of radiation absorbed by a gram of material is called
A) rad.
B) sievert.
C) curie.
D) rem.
E) becquerel

38. Two technicians in a nuclear laboratory were accidently exposed to radiation. If Technician #1 was exposed to 8mGy and Technician #2 to 5 rad, which technician received more radiation.
(1 Gy = 100 rad)
A) Technician #1
B) Technician #2
C) They both received the same.

Convert mGy to rad so they are both in rad and you can compare. (You could take them to mGy.)

$$\text{Tech \#1} = \frac{8\,mGy}{} \left| \frac{Gy}{1000\,mGy} \right| \frac{100\,rad}{1\,Gy} = 0.8\,rad \quad \#1$$

39. A sample of technetium-99m has an activity of 1.5 Ci. How many disintegrations occur in the technetium-99m sample in 5.0 sec? ($1\,Ci = 3.7\times10^{10}\,Bq$)
A) $5.6 \times 10^{10}$
B) $2.8 \times 10^{11}$
C) $1.1 \times 10^{10}$
D) 7.5
E) $2.0 \times 10^{-10}$

$Ci$ = disintegration per second of 1g radium

$Bq$ = disintegrations per second

convert Ci to Bq then multiply by 5 sec

$$\frac{1.5\,Ci}{} \left| \frac{3.7\times10^{10}\,Bq}{1\,Ci} \right| 5\,secs = 2.8\times10^{11}\,disintegrations$$

40. A patient receives 10 mrads of gamma radiation. If the factor that adjusts for biological damage for gamma radiation is 1, how many mrems did the patient receive?
A) 2 mrem
B) 5 mrem
C) 10 mrem
D) 20 mrem
E) 200 mrem

$$(10\,mrads)(1) = 10\,mrems$$

41. The **activity** of a radioisotope is defined as:
A) the radiation absorbed by a gram of material
B) the biological effect of different kinds of radiation
C) the amount of radiation absorbed by a material
D) the number of disintegrations per second
E) rad multiplied by a factor

42. The unit(s) that are used to describe activity is(are):
A) gray (Gy)
B) becquerel (Bq)
C) rad
D) Curie (Ci)
E) (b) and (d)

43. The unit that measures radiation by the biological effects is:
A) gray (Gy)
B) becquerel (Bq)
C) rad
D) rem
E) sievert (Sv)

44. The unit(s) used to measure the amount of radiation absorbed by a material (ex: human tissue) is(are):
A) gray (Gy)
B) becquerel (Bq)
C) rad
D) Curie (Ci)
E) (a) and (c)

45. Biological damage (rem) can be calculated by:
A) multiplying the absorbed dose (rad) by a factor that adjusts for biological damage.
B) the number of disintegrations per second.
C) dividing the absorbed dose (rad) by a factor that adjusts for biological damage.
D) with a Geiger Counter.
E) the severity of the patient's cancer.

46. Sodium-24 has a half-life of 15 hours. How many hours is three half-lives?
A) 60 hours
B) 45 hours     $15 \times 3 = 45$ hours
C) 30 hours
D) 15 hours
E) 7.5 hours

47. The half-life of a radioisotope is
A) one-half of the time it takes for the radioisotope to completely decay to a nonradioactive isotope.
B) the time it takes for the radioisotope to become an isotope with one-half of the atomic weight of the original radioisotope.
C) the time it takes for the radioisotope to become an isotope with one-half the atomic number of the original radioisotope.
D) the time it takes for the radioisotope to lose one-half of its neutrons.
E) the time it takes for one-half of the sample to decay.

48. Krypton-79 has a half-life of 35 hours. How many half-lives have passed after 105 hours?
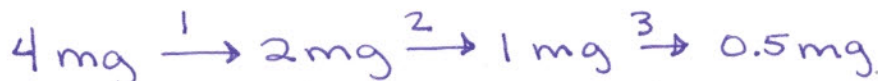A) 1 half-life
B) 2 half-lives
C) 3 half-lives
D) 4 half-lives
E) 5 half-lives

$$\frac{105 \text{ hours}}{35 \text{ hours}} \bigg| \frac{\text{half-life}}{} = 3 \text{ half-lives}$$

49. The half-life of bromine-74 is 25 min. How much of a 4.0 mg sample is still active after 75 min?
A) 0.50 mg
B) 1.0 mg
C) 2.0 mg
D) 0.25 mg
E) 4.0 mg

$$\frac{75 \text{ min}}{25 \text{ min}} \bigg| \frac{\text{half-life}}{} = 3 \text{ half-lives}$$

$$4 \text{ mg} \xrightarrow{1} 2 \text{mg} \xrightarrow{2} 1 \text{ mg} \xrightarrow{3} 0.5 \text{mg}$$
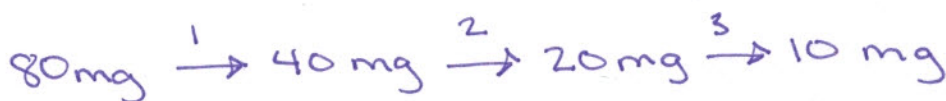
each arrow represents 1 half-lives.

50. Technetium-99m is an ideal radioisotope for scanning organs because it has a half-life of 6.0 hours and is a pure gamma emitter. Suppose that 80 mg were prepared in the technetium generator this morning. How many milligrams of technetium-99m would remain after 18 hours?
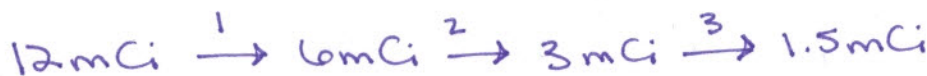A) 15 mg
B) 5 mg
C) 10 mg
D) 20 mg
E) none

$$\frac{18 \text{ hours}}{6 \text{ hours}} \bigg| \frac{\text{half-life}}{} = 3 \text{ half-lives}$$

$$80 \text{mg} \xrightarrow{1} 40 \text{ mg} \xrightarrow{2} 20 \text{mg} \xrightarrow{3} 10 \text{ mg}$$

51. A sample of sodium-24 with an activity of 12 mCi is used to study the route of blood flow in the circulatory system. If sodium-24 has a half-life of 15 hours, what is the activity after three half-lives?
A) 12 mCi
B) 6 mCi
C) 3 mCi
D) 1.5 mCi
E) 0 mCi

not needed

$$12 \text{mCi} \xrightarrow{1} 6 \text{mCi} \xrightarrow{2} 3 \text{mCi} \xrightarrow{3} 1.5 \text{mCi}$$

52. Strontium-85, used for bone scans, has a half-life of 65 days. How long will it take for the radiation level of Strontium-85 to drop to one-fourth of its original level.
A) 65 days
B) 130 days
C) 195 days
D) 260 days
E) 266 days

to visualize, pretend you have 100Ci.
One fourth will be 25 Ci

$$100 \text{Ci} \xrightarrow{1} 50 \text{ Ci} \xrightarrow{2} 25 \text{Ci}$$

It takes 2 half-lives to reach 1/4 radiation.
$$65 \times 2 = 130 \text{ days}$$

53. What type of imaging technique uses the formula: $^{18}_{9}F \rightarrow {}^{18}_{8}O + {}^{0}_{+1}e$
A) MRI
B) CT
C) PET  — positron emission tomography
D) SMT
E) RTS

↑ positron

54. An imaging technique in which a computer monitors the degree of absorption of X-ray beams is known as
A) positron emission tomography (PET).
B) magnetic resonance imaging (MRI).
C) computerized tomography (CT).
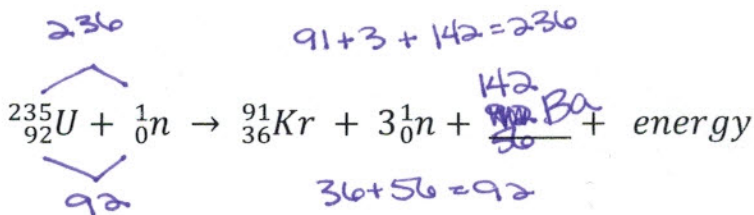D) radioactive iodine uptake (RAIU).
E) a scan.

55. An imaging technique that detects the energy emitted by hydrogen atoms in a magnetic field is known as
A) positron emission tomography (PET).
B) computerized tomography (CT).
C) magnetic resonance imaging (MRI).
D) radioactive tracer study.
E) super magnetic tomography (SMT).

56. When an atom of uranium-235 is bombarded with neutrons, it splits into smaller nuclei and produces a great amount of energy. This nuclear process is called
A) fission.
B) fusion.
C) decomposition.
D) chain reaction.
E) ionization.

236

91 + 3 + 142 = 236

57. Fill in the nuclear fission reaction: $^{235}_{92}U + {}^{1}_{0}n \rightarrow {}^{91}_{36}Kr + 3{}^{1}_{0}n + \underline{\quad}{}^{142}_{56}Ba + energy$

A) $^{142}_{56}Ba$

B) $^{144}_{56}Ba$

C) $^{1}_{0}n$

D) $^{236}_{92}U$

E) $^{142}_{54}Xe$

92

36 + 56 = 92

atomic # 56 = barium

58. What does Einstein's equation E=mc², explain?
A) The amount of energy released when mass is lost in a fission reaction.
B) The amount of energy released when mass is lost in a fusion reaction.
C) The energy of the radiation in alpha decay.
D) The energy of the radiation in beta decay.
E) The energy of gamma rays.

59. What begins nuclear fission?
A) Radioactive materials fission by themselves.
B) A spark.
C) Nuclear fission has always been occurring on the Sun.
D) Bombardment by high-energy particles into a radioactive atom.
E) A particle accelerator.

60. What does the "critical mass" describe?
A) The amount of heat given off during a fission reaction.
B) The amount of fuel required for a fission reaction to maintain itself without adding more fuel.
C) The amount of radioactive material required to make it explosive.
D) The amount of radioactive material needed to begin nuclear fission
E) The amount of radioactive material needed to begin nuclear fusion.

61. What was required to detonate an atomic bomb and achieve critical mass?
A) 6 tons of radioactive material inside the bomb.
B) The impact of the bomb hitting the ground.
C) A fuse to ignite the radioactive material.
D) TNT was detonated around the outside of the radioactive material.
E) Bombs don't have to reach critical mass to explode.

62. Can nuclear reactors explode?
A) No
B) No
C) No
D) No
E) All of the above

63. In the Sun, nuclei of hydrogen combine to form a larger nucleus and release a great amount of energy. The process is known as
A) fission.
B) fusion.
C) metathesis.
D) chain reaction.
E) ionization.

*For problems 65-69, indicate weather each of the following is characteristics of fission or fusion*

a. both fission and fusion
b. fission
c. fusion

64. A large nucleus is split into smaller nuclei  fission

65. Very high temperatures must be achieved to initiate the reaction.  fusion

66. This process produces radioactive by-products  fission

67. Large amounts of energy are released.  both

68. Two small nuclei combine to form a larger nucleus.  fusion