1.06 WORKSHEET #1

1. A worker accidentally ingested one millicurie of I131. I131 has a half-life of 8 days. How many disintegrations per second of I131 are in the workers body after 5 days? How many dpm would there be after 430 days if it were tritium with a 12-year half-life?

2. A sample of I131 (half-life = 8 days) is kept for 80 days, at which time the activity is 1 microcurie. What was the original activity?

3. If a sample of wood has gone through 4 half lives of carbon-14. The half-life of Carbon-14 is 5740 years.

   a. How old is the wood?

   b. What percent of the original carbon-14 remains in the wood?

   c. What percent of the original carbon-14 has decayed from the wood?

4. A particular nuclide has a half-life of 3 years. It has been on site for 14 months. How many half-lives has it been through since it came on site?

5. A particular nuclide has been on site for 456 days. It has been through 0.876 radioactive half-lives. What is its half-life?

6. A particular nuclide has been here for 4 months it has been through 6 half lives. What is its half-life?

7. A gamma spectroscopy source contains 1.05 uCi of Cd109 when new. In order for the source to remain usable, it must have a Cd109 activity of 0.65 uCi. How long can the source be used before needing replacement?

8. Na24 is produced during neutron irradiation of a product. The product is not safe to handle until 55 hours has elapsed and the activity has decayed to 17 uCi. What is its initial activity?

9. A 1.02 Ci Ir-192 source has decayed by 27.6% since its manufacture. How long has it been since its manufacture?

1.06 WORKSHEET #1 KEY

1.

$$A_t = A_o\left(\frac{1}{2}\right)^n \quad \Rightarrow \quad \mathrm{A_t} = 1\ \mathrm{mCi}\left(\frac{1}{2}\right)^{\frac{5\ \mathrm{days}}{8\ \mathrm{days}}} = 0.648\ \mathrm{mCi} \quad \Rightarrow$$

$$\mathrm{X\ dps} = 0.648\ \mathrm{mCi} \times 2.22\mathrm{E09}\,\frac{\mathrm{dpm}}{\mathrm{mCi}} \times \frac{1\ \mathrm{dps}}{60\ \mathrm{dpm}} = 2.40\mathrm{E07}\ \mathrm{dps}$$

2.

$$A_t = A_o\left(\frac{1}{2}\right)^n \quad \Rightarrow \quad \frac{\mathrm{A_f}}{\left(\frac{1}{2}\right)^{\mathrm{n}}} = \mathrm{A_o} \quad \Rightarrow \quad \frac{1\ \mu\mathrm{Ci}}{\left(\frac{1}{2}\right)^{\frac{80\ \mathrm{days}}{8\ \mathrm{days}}}} = \mathrm{A_o} = 1.02\mathrm{E03}\ \mu\mathrm{Ci}$$

3. a.

$$\frac{5740\ years}{half-life} * \frac{4\ half-lives}{} = 2.30E04\ years$$

b. 6.25 %

c. 93.75 %

4.

$$\mathrm{n} = \frac{\mathrm{t}}{\mathrm{t}_{\frac{1}{2}}} \quad \Rightarrow \quad \frac{14\ \mathrm{months}}{36\ \mathrm{months}} = 0.389\ \mathrm{half-lives}$$

5.

$$\mathrm{n} = \frac{\mathrm{t}}{\mathrm{t}_{\frac{1}{2}}} \quad \Rightarrow \quad \frac{\mathrm{t}}{\mathrm{n}} = \mathrm{t}_{\frac{1}{2}} \quad \Rightarrow \quad \frac{456\ \mathrm{days}}{0.876} = 520.5\ \mathrm{days}$$

6.

$$\mathrm{n} = \frac{\mathrm{t}}{\mathrm{t}_{\frac{1}{2}}} \quad \Rightarrow \quad \frac{\mathrm{t}}{\mathrm{n}} = \mathrm{t}_{\frac{1}{2}} \quad \Rightarrow \quad \frac{4\ \mathrm{months}}{6\ \mathrm{half-lives}} = 0.667\ \mathrm{months\ or\ 20\ days}$$

7.

$$A_t = A_o\left(\frac{1}{2}\right)^n \Rightarrow \frac{\log\left(\frac{A_f}{A_o}\right)}{\log 0.5} = n \Rightarrow \frac{\log\left(\frac{0.65}{1.05}\right)}{\log 0.5} = n = 0.698187$$

$$n = \frac{t}{t_{\frac{1}{2}}} \Rightarrow n * t_{\frac{1}{2}} = t \Rightarrow 0.698187 * 462 \text{ days} = t = 319.6 \text{ days}$$

8.

$$A_t = A_o\left(\frac{1}{2}\right)^n \Rightarrow \frac{A_f}{\left(\frac{1}{2}\right)^n} = A_o \Rightarrow \frac{17\ \mu Ci}{\left(\frac{1}{2}\right)^{\frac{55 \text{ hours}}{14.95 \text{ hours}}}} = A_o = 217.7\ \mu Ci$$

9.

$$A_t = A_o\left(\frac{1}{2}\right)^n \Rightarrow \frac{\log\left(\frac{A_f}{A_o}\right)}{\log 0.5} = n \Rightarrow \frac{\log\left(\frac{0.73848}{1.02}\right)}{\log 0.5} = n = 0.4659$$

$$n = \frac{t}{t_{\frac{1}{2}}} \Rightarrow n * t_{\frac{1}{2}} = t \Rightarrow 0.4659 * 73.83 \text{ days} = t = 34.40 \text{ days}$$

1.06 WORKSHEET #2

A pilot-plant food irradiator is being built to test the feasibility of constructing a larger facility. The food will pass by an unshielded Co-60 point source on a conveyer belt at a constant speed and distance. The food will be exposed for a total time of 50 minutes at a distance of 6 feet from the source.

The plant wants to operate for 4 years without altering the distance, conveyor speed or source activity. Each article of food must receive at least 500 Rad, but no more than 1000 Rad.

In addition, the source must be retracted into a lead shield for maintenance entries. The shield must reduce the dose rate to 100 mRem/hr or less at 2 feet from the source.

Co-60 data
Half life ($t_{½}$) = 5.27 years
Two γ emissions: 1.33 Mev 100%
1.17 Mev 100%

Shielding value for lead: HVL = 0.602 " TVL = 2.0"

1. What is the minimum and maximum curie content range for the source?

2. What is the minimum thickness (in inches) for the lead shield?

1.06 WORKSHEET #2 KEY

1. minimum curie content = 2437 ci
   (criteria is having 1440 ci when source is 4 yrs old to give 500 Rad/50 minutes)

   maximum curie content = 2880 ci
   (criteria is not exceeding 1000 Rad/50 minutes when source is new)

2. minimum lead thickness = 10.07 inches
   (criteria is maximum curie content of 2880 ci)

1.06 WORKSHEET #3

A crucial piece of safety equipment is calibrated everyday at 8:00 AM using an Ir192 source (half life = 78.83 days). By procedure, the source must have an activity ≥ 30,000 dpm, and ≤ 50,000 dpm. At midnight (0000) March 22, 2003; the source activity was 35,000 dpm. (use at least 2 decimals in all calculations)

1. On what date and time (to the nearest hour) will the source become unusable?

2. It takes ten days for a new source to arrive from the manufacturer after being ordered. Your manager wants the new source to arrive on the same day that the old source becomes unusable. When should you order it?

3. Your manager also wants the source to be usable the day it arrives, yet still get the absolute maximum useful life span out of it. How much activity should you order on the source?

4. While you are on the phone with the source manufacturer sales rep., they inform you that they can only process requests in units of ηci. How much should you order?

5. What is the total usable life span of the new source (days, hours, minutes)?

1.06 QUIZ

1. Among stable isotopes, as the number of protons increases, how does the neutron/proton ratio change?

    a. Remains 1 to 1
    b. Approaches 1 to 1.5
    c. Approaches 1.5 to 1
    d. No predictable trend

2. The property of certain nuclides to spontaneous emit radiation is called what?

    a. Nuclear instability
    b. Radioactivity
    c. Fission
    d. Half life

3. The process by which a nucleus spontaneously disintegrates by one or more discreet energy steps until a stable state is reached is called what?

    a. Gamma decay
    b. Alpha decay
    c. Beta minus decay
    d. Radioactive decay

4. Why are fission products unstable?

    a. Too large a proportion of neutrons to mass defect
    b. Too large a proportion of protons to mass defect
    c. Too large a proportion of neutrons to protons
    d. Too large a proportion of protons to neutrons

5. Current regulations define the curie (Ci) as what?

    a. 3.7 E 10 dps
    b. 3.7 E 10 dpm
    c. 2.22 E 12 Bq
    d. 2.22 E 12 dps

6. What is the definition of one becquerel (Bq)?

   a. 1 dps
   b. 1 dpm
   c. 3.7 E 10dpm
   d. 2.22 E 12 dps

7. What is the term used to describe the “activity per unit mass”?

   a. Decay constant
   b. Specific activity
   c. N : P ratio
   d. Gram atomic mass

8. "Exposure" (X) is a measure of ionization produced in air by what type of radiation?

   a. Gamma
   b. Particulate
   c. Any type
   d. Gamma and X-ray

9. What are the units of "Absorbed Dose" (D)?

   a. Rad
   b. Roentgen
   c. Rem
   d. Ergs

10. What are the units of "Dose Equivalent" (H)?

    a. Curie
    b. Gray
    c. Becquerel
    d. Sievert

11. "Quality Factor" (Q) is used to relate what two quantities?

    a. Atomic mass units to Mev per nucleon
    b. English units to SI units
    c. Absorbed dose to biological damage
    d. Becquerel to disintegration per minute

12. One Rem is equal to how many sieverts (Sv)?

    a. .01 Sv
    b. 1 Sv
    c. 100 Sv
    d. 2.22 Sv

13. 3.7 E 10 gray (Gy) is equal to how many Rad?

    a. 3.7 E 12 Rad
    b. 1.0 E 2 Rad
    c. 2.7 E - 11 Rad
    d. 2.22 E 10 Rad

14. List two aspects associated with the decay of a radioactive nuclide?

15. On what page in the Chart of the Nuclides will you find a figure depicting the three naturally occurring radioactive decay chains?

16. Using only the most prominent decay mode, what is the stable end product of Pu 241 ?

17. Identify the following decay mode: ${}^{A}_{Z}X \rightarrow {}^{A}_{Z+1}Y + \beta^{-} + \bar{\nu}$

18. What is the Atomic Number of Au198?

19. What is the most prominent decay mode of Pa227.?

20. What is the gamma decay energy of Bi208 in units of Mev?

21. What is the half life of Ni66? (Include units.)

22. How many neutrons does Pm143 have?

23. Complete the following chart.

Radiation	Symbol	Particulate Y or N	Charge
Alpha			
Beta minus			
Gamma			

24. Calculate the half life:

Exactly 3 hours ago, a radioactive sample measured 5 ηCi of activity. Now it measures 412 pCi of activity. What is the half life of the sample (in units of minutes)? Show all work.

1.06 QUIZ KEY

1. c
2. b
3. d
4. c
5. a
6. a
7. b
8. d
9. a
10. d
11. c
12. a
13. a
14. Mode of decay or energies of emissions; types of emissions or rate of decay
15. Page 11
16. ^{209}Bi
17. Beta minus
18. 79
19. Alpha decay
20. 2.6144 MeV
21. 54.6 hours
22. 82
23.

Radiation	Symbol	Particulate Y or N	Charge
Alpha	α	Y	+2
Beta minus	β^-	Y	-1
Gamma	γ	N	0

24. 50 minutes