

Unit 4

Cobalt-60 (${}^{60}_{27}\text{Co}$) provides gamma radiation, and has long been used in the treatment of cancer in “external beam therapy”.

Problem 4.1

Identify the species that upon “neutron capture” produces Cobalt-60 (${}^{60}_{27}\text{Co}$).

(a). ${}^{61}_{27}\text{Co}$

*(b). ${}^{59}_{27}\text{Co}$

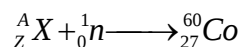
(c). ${}^{59}_{28}\text{Ni}$

(d). ${}^{61}_{28}\text{Ni}$

(e). ${}^{60}_{26}\text{Fe}$

Answer

Strategy: A neutron is represented by ${}_0^1n$. Balance the equation



Balance mass numbers, $A+1=60$, or $A=59$

Balance atomic numbers, $Z + 0 = 27$, or $Z=27$, hence the species is Co . Thus, the species is ${}^{59}_{27}\text{Co}$.

Problem 4.2

The half-life of Cobalt-60 (${}^{60}_{27}\text{Co}$) is 5.27 years. The mass of a sample of Cobalt-60 is initially 10.0 mg. How much Cobalt-60 will remain after 15.8 years?

(a). 3.00 mg

(b). 3.33 mg

(c). 5.00 mg

(d). 2.50 mg

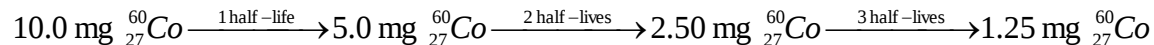
*(e). 1.25 mg

Answer

Strategy: Determine the number of half-lives, then the masses after successive half-lives.

$$\text{Number of half-lives} = 15.8 \text{ years} \times \frac{1 \text{ half-life}}{5.27 \text{ years}} = 3.00 \text{ half-lives} \quad (3 \text{ sf})$$

The decay of the sample is shown below over 3 half-lives:



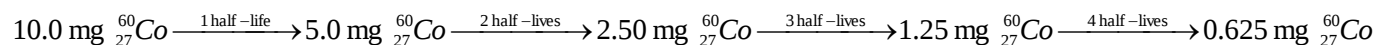
Problem 4.3

The half-life of Cobalt-60 (${}^{60}_{27}\text{Co}$) is 5.27 years. The mass of a sample of Cobalt-60 is initially 10.0 mg. How much time will it take such that 0.625 mg Cobalt-60 remains?

- (a). 5.27 years
- (b) 10.5 years
- (c). 15.8 years
- *(d). 21.1 years
- (e). 26.4 years

Answer

Strategy: Determine the amounts in successive half-lives, then the time



$$\text{Time} = 4 \text{ half-lives} \times \frac{5.27 \text{ years}}{1 \text{ half-life}} = 21.1 \text{ years} \quad 3\text{sf}$$

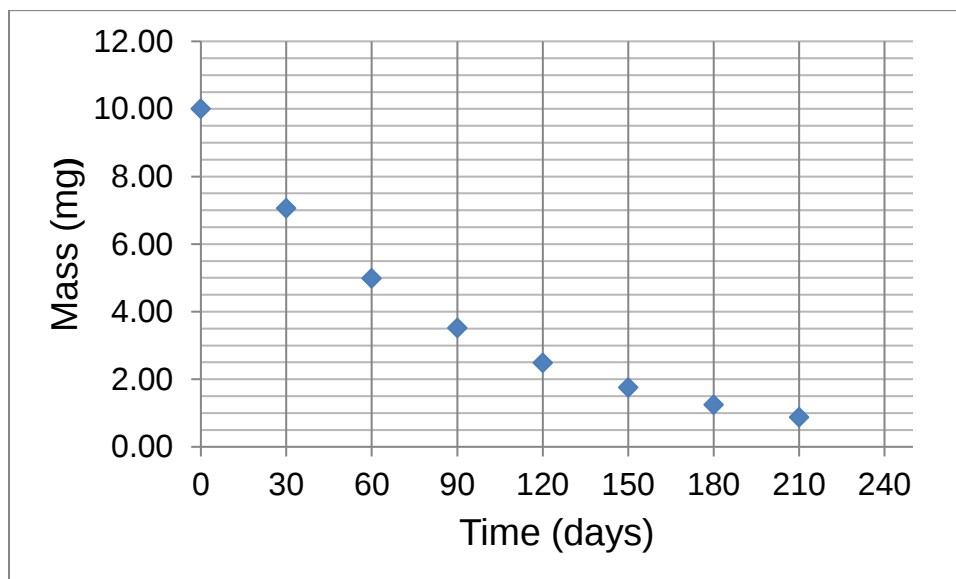
Here are a number of questions pertaining to Iodine-125

<https://en.wikipedia.org/wiki/Iodine-125>

Iodine-125 (^{125}I) is a **radioisotope** of **iodine** which has uses in **radiation therapy** to treat a number of conditions, including **prostate cancer**, **uveal melanomas**, and **brain tumors**.

Problem 4.4

The following experiment was carried out to determine the half-life of Iodine-125. The decay of a sample of Iodine-125, whose initial mass was 10.00 mg is shown below.



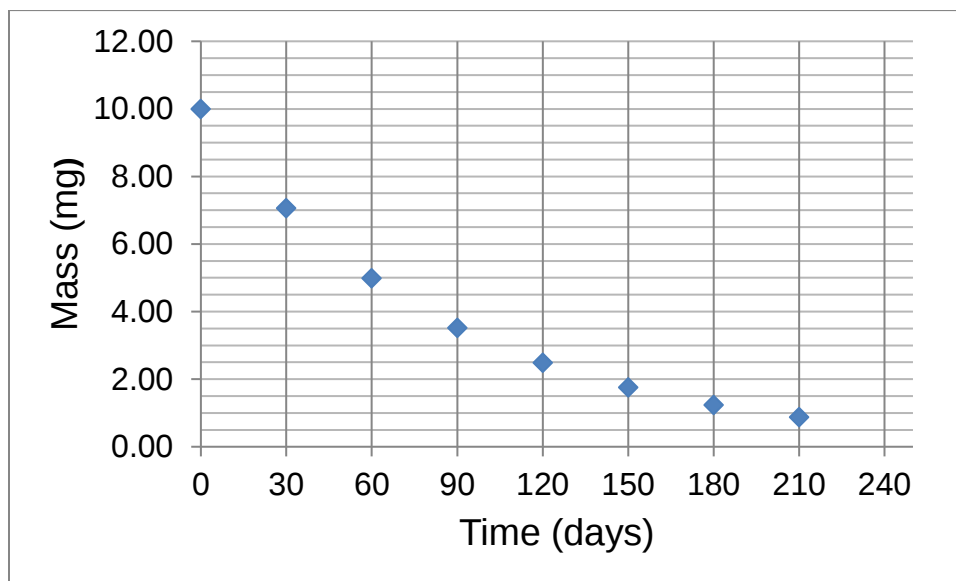
Fill in the blank. Based on the data above, the half-life of Iodine-125 is _____ days.

Answer

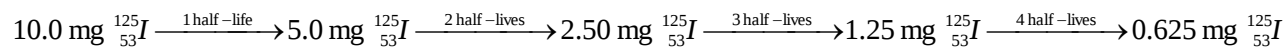
The initial mass is 10.00 mg. The time taken for the mass to decrease to 5.00 mg is the first half-life that equals 60 days. We note that successive half-lives are equal in nuclear reactions.

Problem 4.5

The decay of a sample of Iodine-125, whose initial mass was 10.00 mg is shown below. After how many days will the mass of Iodine-125 remaining be 0.625 mg?

**Answer**

Strategy: Determine the amounts in successive half-lives, then the time



$$\text{Time} = 4 \text{ half-lives} \times \frac{60 \text{ days}}{1 \text{ half-life}} = 240 \text{ days}$$

Problems 4.6 – 4.9

^{90}Y plays a significant role in the treatment of [hepatocellular carcinoma](#), [leukemia](#), and [lymphoma](#).

Problem 4.6 (Fill in the blanks)

In a nucleus of Yttrium-90 (^{90}Y), the number of protons is _____ and the number of neutrons is _____.

Answer

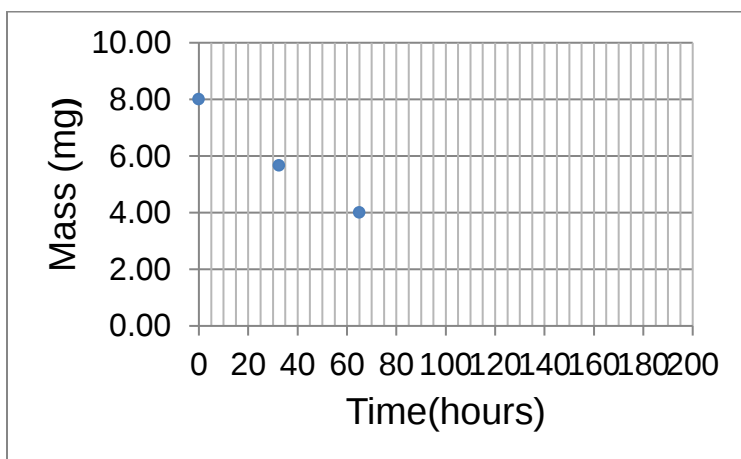
The number of protons is the atomic number, which is 39 (from the Periodic Table).

Number of Protons + Number of Neutrons = Mass Number

Number of Neutrons = Mass number – Number of Protons = $90 - 39 = 51$

Problem 4.7

The decay of a sample of Yttrium-90 (^{90}Y), whose initial mass was 8.00 mg is shown below.



The half-life is _____ hours.

Answer

The initial mass is 8.00 mg. The time taken for the mass to decrease to 4.00 mg is the first half-life that equals 65 hours.

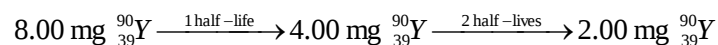
Problem 4.8

Based on the figure above, how much time will it take Yttrium-90 (^{90}Y) to remain to decay to 2.00 mg? Assume that time can be reported to the nearest hour.

- (a). 85 hours
- (b) 100 hours
- (c). 120 hours
- * (d). 130 hours
- (e). 163 hours

Answer

Strategy: Determine the amounts in successive half-lives, then the time



$$\text{Time} = 2 \text{ half-lives} \times \frac{65 \text{ hours}}{1 \text{ half-life}} = 130 \text{ hours}$$

Problem 4.9

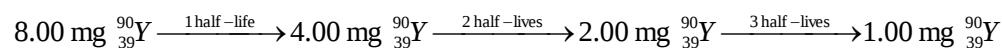
Based on the figure above, what is the mass of Yttrium-90 (^{90}Y) after 195 hours?

- (a). 1.50 mg
- * (b) 1.00 mg
- (c). 0.500 mg
- (d). 0.250 mg
- (e). 0.125 mg

Answer

Strategy: Determine the number of half-lives, then the masses after successive half-lives.

$$\text{Number of half-lives} = 195 \text{ hours} \times \frac{1 \text{ half-life}}{65 \text{ hours}} = 3.0 \text{ half-lives} \quad (2 \text{ sf})$$



<https://jeccr.biomedcentral.com/articles/10.1186/1756-9966-27-52>

PET scans were initially used to study the brain and the heart, but today it is used mainly in oncology. PET scanning is a non-invasive imaging method that differs from others because it observes "in vivo" metabolic activity using radio-isotopes. The most commonly used isotope in PET scans is fluorine-18 with a half-life of 110 minutes.

Problem 4.10 (Similar to your problem 20)

Fluorine-18, which is used in PET scans, has a half-life of 110 minutes. If a compound used in PET scans contains 18.0 mg of Fluorine-18 is prepared at 8:00 A.M., how much Fluorine-18 will remain at 11:40 A.M., i.e., after two half-lives?

- (a). 16.0 mg
- (b) 9.00 mg
- *(c). 4.50 mg
- (d). 2.25 mg
- (e). 1.125 mg

Strategy: Determine the masses after successive half-lives.

